

The Epidemiology of
Fractures of the
Upper Limb, Lower Limb
and Pelvis in Adults

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Declaration

This thesis and its composition are entirely my own work. The contributions and assistance of others in data analysis have been appropriately acknowledged. The research described and presented here has been carried out by me, under the supervision of Professor C.M. Court-Brown. I have not submitted this work in candidature for any other degree, diploma of professional qualification.

Where other sources of information are cited, full references are provided.

Stuart A Aitken

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II. SUMMARY / ABSTRACT

The introductory section of this thesis outlines the importance of obtaining accurate and reliable skeletal fracture pattern data. The difficulties commonly encountered by injury epidemiologists in obtaining fracture data are discussed, and a review of the currently available literature is presented.

The substantial variation in reported fracture incidence in the literature is further investigated in Section 2. Using a cohort of fracture patients from the Edinburgh population, this study aimed to investigate the effect of employing two different methods of obtaining numerator fracture data on the number and patterns of fractures reported. The results illustrate the marked difference that exists between numerator data obtained from emergency department (ED) sources and data obtained from the orthopaedic trauma unit (OTU). The positive predictive value (PPV) of a correct ED outpatient fracture diagnosis was only 74%, meaning that for every four fractures diagnosed and recorded in the ED, one of these will have been coded incorrectly. Fractures of the carpus, proximal tibia, proximal radius, calcaneus, talus and midfoot were miscoded more frequently than the average, while those of the clavicle, proximal humerus, metacarpus, metatarsus and distal radius were coded with greater accuracy. These results suggest that epidemiological fracture research using ED numerator data is likely to overestimate adult fracture incidence when compared to studies obtaining data from orthopaedic sources.


Section 3 examines the range and pattern of acute fractures of the upper limb, lower limb and pelvis that occur in Edinburgh adults. The results of a 12 month longitudinal observational study are presented, including a detailed review of the patterns of fracture types encountered and the modes of injury involved in fracture occurrence. Where possible a comparison is made with historical data from the Edinburgh, as well as the existing fracture epidemiology literature.

The socioeconomic status of patients is an important factor in the distribution of morbidity and disability in many areas of medicine. Section 4 of this thesis explores the association between deprivation, as measured by the Scottish Index of Multiple Deprivation (SIMD) and the incidence of fractures in Edinburgh adults. Logistic regression analysis was used to control for the influence of a number of variables known to have an effect on fracture patterns, such as the age and gender of the patient, the injury mode involved and the fracture type. The results show that increasing socioeconomic deprivation correlates with increasing fracture incidence, even after controlling for confounding variables. A stronger correlation exists in men than in women, and the fracture incidence seen in the most affluent decile is only 50% of that seen in the most deprived group. A stronger correlation exists for certain fracture types, namely fractures of the metacarpus, distal radius, proximal humerus and ankle.

The final section contains a discussion of the relevance of the findings presented in Sections 2, 3 and 4 and how they relate to the existing fracture epidemiology literature. This section also considers which fracture types should now be considered as fragility fractures. The significant strengths and considerable limitations of this thesis, including issues related to the numerator, the denominator, causation and multiplicity in epidemiological fracture research, are discussed in detail. Suggestions for future work are presented.

III. ETHICAL APPROVAL

The research presented in this thesis was carried out following approval from the Regional Research Ethics Service.

South East Scotland Research Ethics Service		
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Name: Stuart Aitken	Date: 03/03/2008	
Address: Orthopaedic Research Fellow Royal Infirmary of Edinburgh 51 Little France Crescent Old Dalkeith Road Edinburgh EH16 4SA	Your Ref: Our Ref: NR/0802AB11 Enquiries to: Alex Bailey Extension: Direct Line: 0131 536 9050 Email: alex.bailey@nhslothian.scot.nhs.uk	

Dear Stuart,

Full title of project: The epidemiology of adult fractures.

You have sought advice from the South East Scotland Research Ethics Service on the above project. This has been considered by the Scientific Officer and you are advised that, based on the submitted proposal, it does not need NHS ethical review under the terms of the Governance Arrangements for Research Ethics Committees in the UK. The advice is based on the following:

- *The project is an audit using only data obtained as part of usual care but note the requirement for Caldicott Guardian approval to permit publication of patient-identifiable information.*

Please note that this advice is issued on behalf of the Research Ethics Service and does not constitute a favourable opinion or an endorsement from a Research Ethics Committee. It may be provided to journal editors, conference organisers or others who require evidence of consideration of the need for ethical review prior to publication or presentation of your results. If you wish you may still decide to apply to a REC, but note that a retrospective ethical opinion cannot be given.

You should retain a copy of this letter with your project file as evidence that you have sought advice from the South East Scotland Research Ethics Service.

Yours sincerely,

Alex Bailey
Scientific Officer
South East Scotland Research Ethics Service

SECTION 1: INTRODUCTION AND LITERATURE REVIEW

1.1 The importance of epidemiological data

“To prevent disease and improve health it is essential to understand why diseases arise..... To do this it is necessary to study the distribution and natural history of diseases in populations and to identify the agents responsible; effective strategies can then be planned.....”

Farmer and Lawrenson¹

Much of medicine and surgery involves the direct and close study of individual patients and conditions. Epidemiology on the other hand, involves the analysis of groups of individuals or entire populations, and is derived from the Greek meaning ‘studies upon people’.

Population studies enhance clinical practice in a number of ways.

Firstly, the most important role of epidemiology is to provide a broader understanding of the causes and patterns of injury and disease. The experience of individual clinicians is often limited by the number of injuries and diseases encountered in day to day practice. If the experience of many clinicians is combined, recorded in a standardised way and appropriately analysed, then new and more reliable data may be obtained. This systematic collection and analysis of injury or disease data is the essence of epidemiology.

Secondly, epidemiological data allow for a better appreciation of the range and variety of injury and disease within a population. This largely unbiased information is more reliable than the experience of the individual clinician, and helps determine the health care needs of the community under scrutiny. In this way, epidemiological data are important in planning health care provision.

Population studies are frequently used to evaluate the outcomes of medical or surgical intervention. Once a new product or procedure has been introduced into clinical practice, it is necessary to continue to monitor its effect on the population. In order to produce reliable results these population studies usually need to be carried out on a large scale. Although they can be time consuming and expensive to perform, they provide valuable information.

Finally, the application of epidemiology to clinical practice allows clinicians to compare groups of people within a given population: those with a specified injury or condition, and those without. In this way, it is possible to look for factors that distinguish affected from unaffected groups. This form of analysis is based upon the assumption that injury or disease does not happen by chance, but rather as the result of a definable and preventable combination of circumstances or individual characteristics. As clinicians learn more about these characteristics, they are able to develop appropriate treatments and preventive strategies.

Gathering epidemiological fracture data for the adult population in Edinburgh assists in the organisation and provision of appropriate adult trauma and orthopaedic services in the Lothian region. The use of inferential statistics allows for the extrapolation of this information and its application to other regions with similar population demographics. The Scottish Research Trust into Trauma (SORT-IT) has collected epidemiological trauma data on a defined adult patient population for twenty years. This pooled information has led to an improved understanding of existing patterns of adult fractures and the numerous predisposing characteristics for fracture occurrence. Most importantly, these data have contributed enormously to the development of efficient and effective fracture management strategies.

1.2 The difficulties in obtaining epidemiological fracture data

There are many difficulties that need to be addressed in designing a study aimed at the collection and analysis of fracture data. Cummings *et al*², in their review of methodological challenges facing injury epidemiologists, identified several key areas:

- i. Numerator problems include the definition, classification, categorisation, and ascertainment of injury.
- ii. Denominator problems include matching numerators to denominators and selecting the most appropriate denominator according to the study objectives.
- iii. Causation issues involve the difficulties in identification and categorisation of the many and varied causes and mechanisms of injury.
- iv. Multiplicity refers to the handling of multiple events data. There are implications in the analysis of multiple injuries in the same individual during a single injury episode or the recurrence of injury in the same individual during the period of study.

NUMERATOR PROBLEMS

Fracture definition

In order to count numbers of fractures it is first necessary to have a clear definition. In contrast to many injury types, the definition of skeletal fracture is relatively straightforward. According to the Oxford English Dictionary³ a fracture (in medical terms) is defined as “a crack or break in bone”. Researchers must also consider a number of specific fracture definitions, and consider their suitability for inclusion or exclusion in a given study. Fatigue (or stress) fractures occur in normal bone as a result of repetitive loading^{4,6}. Fragility (or insufficiency) fractures occur in weakened bone subjected to normal physiological loads^{7,8}. Pathological fractures fall into this fragility fracture category, but the term is used to describe fracture through bone weakened by a primary or secondary malignant process^{9,10}. Periprosthetic fractures are seen in proximity to implanted joint prostheses or other metalwork used in the treatment of skeletal trauma^{11,12}.

Fracture classification and categorisation

Depending on the purpose of the research, fractures can be classified in different ways. Commonly they are broadly classified by anatomical region, *e.g.* upper limb, lower limb, axial skeleton *etc.* They may then be further categorised by the bone involved, *e.g.* humerus, radius, scaphoid *etc.* Further detailed subclassification of individual bones and fracture types

is possible, and forms the basis for a large proportion of the research presented in this thesis. Most modern fracture classification systems are based on a description of the location, the number, and the displacement of fractures lines viewed on plain radiographs. The orthopaedic trauma literature contains a large number of studies whose objective has been to develop detailed classification systems for specific fractures. Examples of well known fracture specific classification systems are shown in Table 1.1 (next page).

In contrast to fracture-specific systems, the Arbeitsgemeinschaft für Osteosynthesefragen (AO) Foundation produced a generic and comprehensive long bone fracture classification system¹³. This system has been adopted and modified by the Orthopaedic Trauma Association (OTA)¹⁴ of the American Academy of Orthopaedic Surgeons who recognised the need to develop a detailed universal system of classification that would standardise research and improve communication among orthopaedic surgeons. The OTA fracture classification system is detailed in full at the Appendix.

Fracture classification systems exist for two main reasons:

- i. For the purposes of epidemiological work, researchers require a system that can successfully *name, describe* and *compare* different fractures.
- ii. In addition, clinicians require a system that is able to *guide treatment* and *predict final clinical outcome* for the individual patient.

The perfect and faultless classification system does not exist, and all systems have their limitations. Ideally, a fracture classification system should be both reliable and valid¹⁵⁻¹⁷. Reliability refers to the ability of the system to return the same result for the same fracture using multiple observers (interobserver reliability) or return the same result using one observer on multiple occasions (intraobserver reproducibility). Validity reflects the ability of the system to correctly characterise the fracture when compared to a 'gold standard'. Unfortunately a true gold standard does not exist. Even detailed forms of radiographic imaging (*e.g.* computed tomography, magnetic resonance imaging) and intraoperative observations are prone to error and can not be considered infallible. Accordingly, the assessment of fracture classification systems is most often confined to measuring reliability, *i.e.* interobserver reliability and intraobserver reproducibility. Observer variability has been found to be a limitation of many fracture classification systems, including the AO system, where many studies have found only fair to poor intraobserver reliability¹⁸⁻²³ (when using the kappa statistical correlation guidelines described by Landis and Koch²⁴).

Authors	Year	Fracture type
<i>Upper Limb</i>		
Ideberg <i>et al</i> ²⁵	1995	Scapula
Kuhn <i>et al</i> ²⁶	1994	Scapula
Ogawa <i>et al</i> ²⁷	1997	Scapula
Robinson CM ²⁸	1998	Clavicle
Neer CS ²⁹	1968	Clavicle
Nordqvist A <i>et al</i> ³⁰	1998	Clavicle
Neer CS ³¹	1970	Humerus
Milch H ³²	1964	Humerus
Jupiter JB and Mehne DK ³³	1992	Humerus
Hahn NF ³⁴ and Steintal D ³⁵	1853, 1898	Humerus
Kocher C ³⁶ and Lorenz H ³⁷	1896, 1905	Humerus
Hertel R <i>et al</i> ³⁸	2004	Humerus
Gartland JJ Jr and Werley CW ³⁹	1951	Radius
Frykman GK ⁴⁰	1967	Radius
Melone CP Jr ⁴¹	1993	Radius
Fernandez DL ⁴²	1993	Radius
Colles	19 th century	Radius
Galeazzi ³⁶	1934	Radius (Galeazzi)
Rettig ME and Raskin KB ⁴³	2001	Radius (Galeazzi)
Mason ML ⁴⁴	1959	Radius
Morrey BF ⁴⁵	1985	Radius
Monteggia	1814	Ulna (Monteggia)
Bado JL ⁴⁶	1967	Ulna (Monteggia)
Morrey BF ⁴⁷	1995	Ulna
Herbert TJ and Fisher WE ⁴⁸	1984	Scaphoid
Teisen H and Hjarbaek J ⁴⁹	1988	Lunate
<i>Axial Skeleton</i>		
Denis F ⁵⁰	1983	Thoracolumbar spine
Magerl F <i>et al</i> ⁵¹	1994	Thoracolumbar spine
Tile M ⁵²	1988	Pelvis
Young JW <i>et al</i> ⁵³	1986	Pelvis
Letournel E ⁵⁴	1980	Pelvis (Acetabulum)
Denis F <i>et al</i> ⁵⁵	1988	Sacrum
<i>Lower Limb</i>		
Pipkin G ⁵⁶	1957	Femur
Brumback RJ <i>et al</i> ⁵⁷	1987	Femur
Garden RS ⁵⁸	1961	Femur
Pauwels F ⁵⁹	1935	Femur
Boyd HB and Griffin LL ⁶⁰	1949	Femur
Evans EM ⁶¹	1949	Femur
Seinsheimer F 3 rd ⁶²	1978	Femur
Schatzker J <i>et al</i> ⁶³	1979	Tibia
Oestern HJ and Tscherne H ⁶⁴	1983	Tibia
Ruedi T <i>et al</i> ⁶⁵	1968	Tibia
Lauge-Hansen N ⁶⁶	1950	Ankle
Danis R ⁶⁷ and Weber B ⁶⁸	1949, 1972	Ankle
Hawkins LG ⁶⁹	1970	Talus
Essex-Lopresti P ⁷⁰	1952	Calcaneus
Sander R <i>et al</i> ⁷¹	1993	Calcaneus

Table 1.1 Fracture specific classification systems in the orthopaedic literature. The author(s), year of publication, and fracture types of interest are shown.

Fracture ascertainment

When a clear definition of skeletal fracture exists and appropriate methods of fracture classification have been chosen, recording and counting fractures can only occur if they are brought to the attention of researchers. Furthermore, researchers must be able to correctly identify fractures using the available investigations. This process is known as fracture ascertainment. In instances where fractures almost always result in a medical encounter (*e.g.* a footballer sustaining an open tibial fracture), and the identification of a fracture on radiographs is straightforward, researchers can expect almost 100% case ascertainment. However, many fractures do not result in the patient presenting to hospital and are managed by general practitioners and allied health care providers, with or without the use of radiographs. Under some circumstances, patients with fractures will not present to the health care services at all. When attempting to identify fractures such as these (*e.g.* rib fractures, vertebral fractures in the elderly, minor toe and finger fractures), researchers may expect case ascertainment to be much lower. A much smaller number of fractures, but inherently difficult to quantify, are those sustained by patients whose injuries are so severe that they result in death soon after the traumatic event. Determining whether skeletal injury was involved with these cases of pre-hospital death is not always possible, and such fracture data are most likely derived from autopsy reports.

When an injured patient presents to the health care services, the identification and recording of a fracture relies almost exclusively on the ability of clinicians to make judgements and interpretations based on the analysis of the often complex patterns of shadows evident on plain radiographs. Clinicians must have the ability to accurately and completely identify fracture lines and understand the origin and nature of the fracture fragments. It is likely that experienced observers are able to identify fractures with greater accuracy than those with less experience^{72, 73}. Accurate fracture ascertainment therefore relies upon the presentation, appropriate investigation and correct identification of injury at the point of contact between the patient and health care services.

DENOMINATOR PROBLEMS

Choosing a denominator

In order to calculate the rate of fractures within a population, researchers must identify and fully define an appropriate denominator. The majority of studies concerned with fracture epidemiology make use of a defined patient population. This is most often the population

that forms the geographical catchment area of the health care facilities used to capture the numerator data.

Matching numerator and denominator

In regions with high visitor numbers the fracture rate may be falsely calculated if researchers fail to exclude non-residents from the denominator. If numerator data are derived solely from adult patient facilities the study design should reflect this, and all children in the population should be removed from the denominator prior to any calculation. In many areas the population will be served by a number of health care facilities. Certain fracture types (*e.g.* spinal fractures, complex hand trauma) may be treated by more than one type of health care facility (orthopaedic, neurosurgical or plastic surgical services) making it difficult to accurately match numerator data to a denominator.

CAUSATION

The multifactorial nature of injury

Many factors contribute to the occurrence of fractures. In pathological terms, fractures are caused by the forces acting upon bone exceeding the bones inherent ability to absorb or withstand force. In epidemiological terms, fractures result from a combination of circumstances or individual characteristics. Fracture data are often defined and categorised in such a way that a certain component cause is assumed to be necessary. This occurs when fractures are defined by their mode of injury, *e.g.* road traffic accident, sporting injury *etc.* This type of definition assumes exposure to a necessary cause or injury mechanism, *e.g.* a direct blow from a moving vehicle, indirect violence suffered by collision with an opponent *etc.* Researchers may need to identify confounding variables that interact with the cause. For example, to compare the risk of sustaining a fracture from road traffic accidents across age groups in a given population, researchers must allow for the fact that certain patient groups will be less likely to own a drivers licence or drive a motor vehicle, and therefore will be less exposed to potential injury.

A number of patient characteristics have an influence on fracture occurrence, but they can be broadly divided into two categories. Trauma related factors include those variables that increase the tendency of the patient to suffer a fall. Bone related factors include skeletal architecture, bone mineral density (BMD), and bone size. At the present time, BMD is the best surrogate measure of the breaking strength of bone⁷⁴. The age-related decline in BMD affects men and women⁷⁵⁻⁷⁸, and a large number of factors have an influence on the rate of

this decline (*e.g.* patient age and gender, premature menopause or hypogonadism, low body weight, ethnic origin, smoking habits, caffeine intake, alcohol abuse and other chronic medical conditions). The influence of social deprivation on disease and injury rates has been the subject of much research⁷⁹⁻⁸². Its effect on fracture incidence and fracture patterns is not as clear, although recent work suggests an increase in adolescent fracture rates in more deprived areas⁸³.

MULTIPLICITY

Dealing with recurrent events

The same individual can sustain several fractures at the same time, or may suffer a fracture on a number of separate occasions within the period of study. When this happens, the assumption that events are statistically independent may not be correct and can complicate the data analysis. Researchers need to be aware of these problems and decide and declare how multiple events data will be treated prior to analysis.

The systematic collection and analysis of fracture data provides clinicians with a broader understanding of the range, variation, and patterns of fractures encountered in a population. Researchers must clearly define and categorise fractures, and choose methods of data collection where case ascertainment is high, in order to avoid missing valuable data. They must clearly define the population of interest, and decide how to define and categorise causation and multiple events. There are many difficulties and sources of error that need to be addressed in the design of epidemiological fracture research. Most difficulties can be dealt with, and error sources minimised, if careful attention is given to the design and implementation of such research. Perhaps most importantly, researchers must clearly state in detail the precise definitions and other methods used in gathering and analysing fracture data. This allows further research to be carried out, under broadly the same sets of circumstances, perhaps on the same population after a period of time, with the intention of identifying time-related fracture trends. Furthermore, if researchers wish to compare fracture patterns between populations from different regions or countries, they must attempt to employ identical research methods if their findings are to be considered strictly comparable. The existing literature on fracture epidemiology suggests that this feat has proven difficult to accomplish.

1.3 Existing literature on adult fracture epidemiology

A number of researchers have attempted to address and overcome the difficulties involved in gathering and analysing adult fracture data.

Fracture distribution curves

One of the earliest reports on adult fracture patterns was produced in 1959 by Buhr and Cooke⁸⁴. They analysed 8,539 fractures over a five-year period in Oxford. The authors did not provide fracture incidence data with relation to the Oxford population, but extrapolated their results to estimate age-specific rates per million head of population in England and Wales. Perhaps most importantly, Buhr and Cooke provided information on the patterns of adult fractures presenting to health care services in their region, and were the first to produce the fracture distribution curves with which we are familiar today. They proposed four basic curves types (Fig. 1.1, next page).

The J shaped curve showed a unimodal distribution affecting older men and women. They referred to this as the ‘post wage-earning’ curve. At that time, it represented fractures commonly seen in the elderly such as those of the proximal humerus, humeral diaphysis, proximal femur and pelvis. The L shaped or ‘pre wage-earning’ curve showed a unimodal peak in young age groups, and represented fractures of the distal humerus, tibial diaphysis and clavicle. The A shaped curve affected young and middle-aged men and was known as the ‘wage earners’ curve. Buhr and Cooke suggested that this occurred in patients who presented with fractures of the hand, metatarsals, toes and spine. They also described two composite curves with either a bimodal (two peaks) male and unimodal (one peak) female distribution or a unimodal male and bimodal female distribution. These curves described fractures of the proximal and distal radius, femoral diaphysis and proximal tibia.

Later studies produced similar distribution curves. Knowelden *et al*⁸⁵ demonstrated J shaped curves for fractures of the proximal humerus, pelvis and proximal femur in an analysis of patients aged at least 35 years. Donaldson *et al*⁸⁶ constructed four curves for proximal femoral, proximal humeral, distal radial and tibial diaphyseal fractures. Johansen *et al*⁸⁷ constructed eight curves covering different body regions: the hip, spine, upper arm, pelvis, forearm and wrist, ankle, hand and digits, and foot and toes.

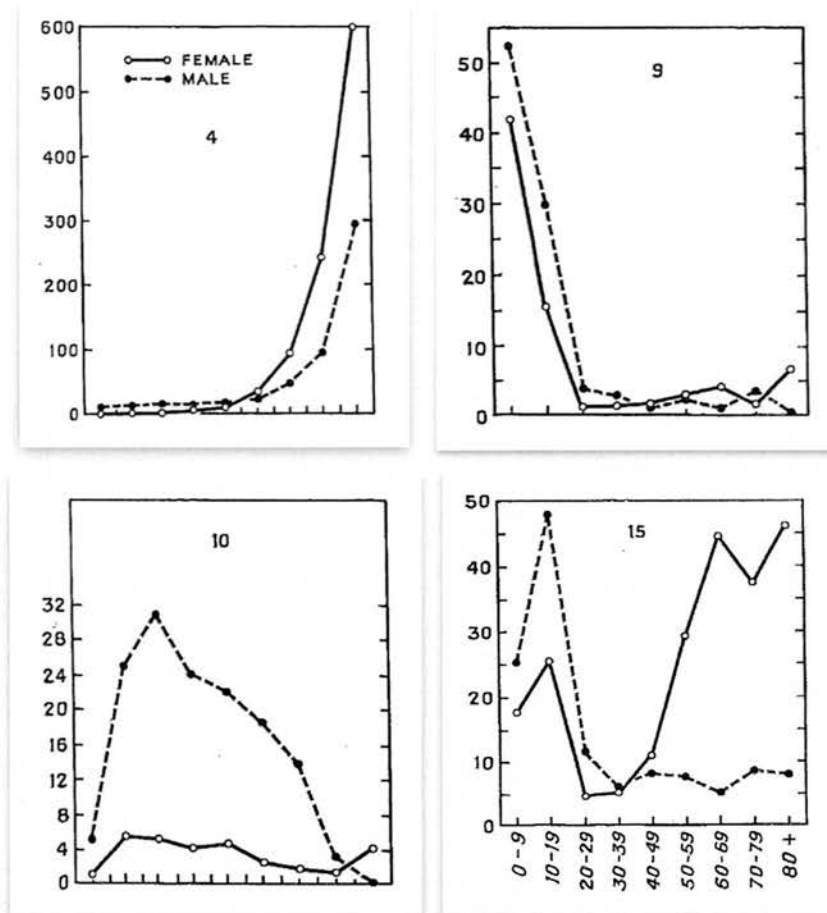


Figure 1.1 The four basic fracture distribution curve types proposed by Buhr and Cooke in 1959⁸⁴. Patient age groups are displayed along the x-axis, and rates of fracture per million head of population are displayed along the y-axis. Clockwise from top-left: the J shaped curve; the L shaped curve; the composite curve; the A shaped curve. (Reproduced with permission from Elsevier publishers).

In 2006, Court-Brown and Caesar⁸⁸ reviewed 5,953 adult fractures of the upper limbs, lower limbs, pelvis and cervical spine. They identified eight different fracture distribution curves into which these fractures could be placed (Fig. 1.2, next page). Type A curves denoted fractures affecting young men and older women (scapula, distal radius, tibial diaphysis, lateral malleolus ankle fractures). Type B curves referred to fractures seen in young men (scaphoid, metacarpal, both-bone forearm fractures). Fractures affecting young adults of both sexes produced a type C curve (talus, and other midfoot fractures). Type D curves displayed a unimodal young male and bimodal female distribution (proximal forearm and distal tibial fractures).

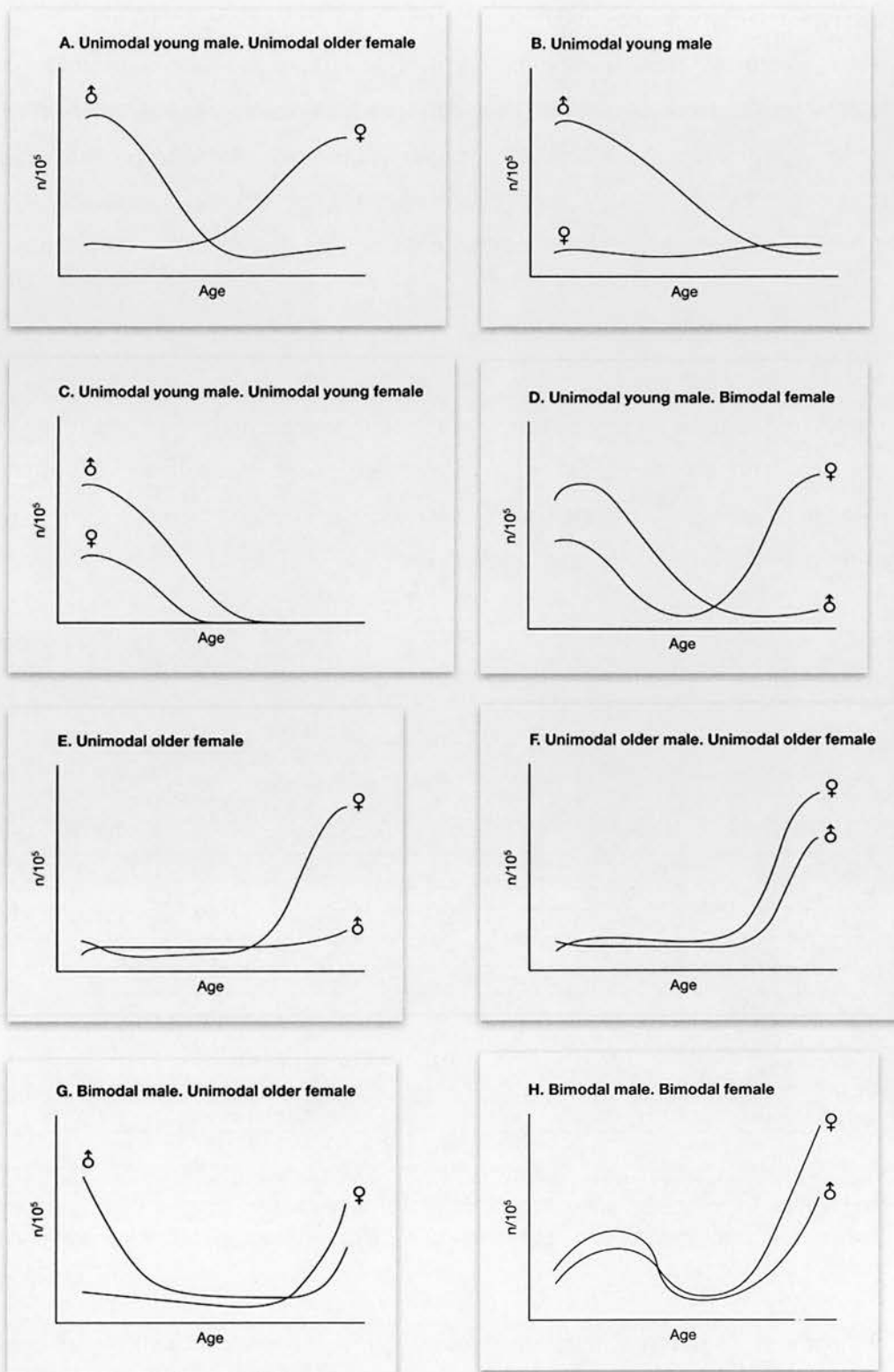


Figure 1.2 The eight fractures distribution curves for adult fractures based on age and gender, proposed by Court-Brown and Caesar⁸⁸. The symbols ♂ and ♀ denote males and females, respectively. A bimodal distribution describes the presence of two peaks in incidence with relation to age, and unimodal represents a single peak. (Reproduced with permission from Lippincott Williams & Wilkins publishers).

The type E curve was created by fractures affecting older women (distal humerus, distal femur, bimalleolar ankle fractures), while the type F curve was used for fractures occurring in older men and women (proximal humerus, proximal femur, proximal ulna). Type G curves were found with fractures affecting young men and older patients of both sexes (clavicle, calcaneus). Finally, type H curves denoted fractures displaying a bimodal distribution in both men and women (humeral diaphysis, radial head, and tibial plateau fractures).

Fracture incidence

Despite the frequency with which fractures are encountered, it has proven difficult to obtain complete data on fracture incidence in all adult age groups. A small number of studies have reported rates of adult fracture in the United Kingdom (UK), Norway and the United States of America (USA) and these are shown in Table 1.2.

Author(s)	Year(s)	Country	Methodology	Incidence (n/1000/yr)		
				Male	Female	Overall
Court-Brown and Caesar ⁸⁸	2000	UK	Orthopaedic & Radiology	11.7	10.7	11.2
Singer <i>et al</i> ⁸⁹	1992-93	UK	Orthopaedic & Radiology	13.2	12.7	12.9
Donaldson <i>et al</i> ⁸⁶	1980-82	UK	Orthopaedic & Radiology	10.0	8.1	9.1
Johansen <i>et al</i> ⁸⁷	1994-95	UK	ED data	23.5	18.8	21.1
Sahlin ⁹⁰	1985-86	Norway	ED data	22.9	21.3	22.8
Fife and Barancik ⁹¹	1977	USA	ED data	26.0	16.0	21.0
Donaldson <i>et al</i> ⁹²	2002-04	UK	Patient questionnaire	41.0	31.0	36.0
Brinker and O'Connor ⁹³	1998-2000	USA	Insurance company data	9.6	7.4	8.5
van Staa <i>et al</i> ⁹⁴	1988-98	UK	GPRD	10.0	10.7	10.3

Table 1.2 Studies reporting the overall fracture incidence in adults. The study author(s), year and region of study, methodology employed in gathering fracture data, and reported fracture incidences are shown. (*ED* = emergency department; *GPRD* = general practice research database).

Of interest is the observed variation in the overall adult fracture incidences reported by these studies. In three reports, the fracture diagnoses were made from radiographs examined by orthopaedic specialists and radiologists, and they reported similar results^{86, 88, 89}. Three investigations utilised emergency department (ED) databases or coding systems, and reported substantially higher fracture incidences^{87, 90, 91}. Donaldson *et al* employed a patient questionnaire strategy to determine the incidence of fractures and reported the highest

overall adult fracture rate of any published study⁹². Brinker and O'Connor obtained medical insurance company data in an attempt to estimate the incidence of fractures in Texas, United States⁹³. Finally, the UK General Practice Research Database (GPRD) was used by van Staa and colleagues in an attempt to define annual fracture rates in England and Wales⁹⁴.

The GPRD comprises the computerised medical records of a large number of participating UK general practices, and its use allows epidemiologists to analyse a regionally diverse group of patients across a large geographical area. The GPRD derives its fracture data from two sources, inpatient discharge letters and ED records, and the validity of fracture data from the GPRD has not been formally reported.

It is likely that differences exist between populations in different countries and between regions within the same country. Fracture incidence is also likely to change with time. However, the reported differences in the overall fracture incidences presented in Table 1.2 are unlikely to be explained by population or time-related trends alone. If researchers wish to compare fracture patterns between populations from different regions or countries, they must attempt to employ identical research methods if their findings are to be considered strictly comparable (see Section 1.2).

The effect of deprivation

Socioeconomic status and the measurable indices of socioeconomic deprivation have an important effect on the health of patients. The literature shows that deprivation has been associated with many diseases such as myocardial infarction⁹⁵, colorectal cancer⁹⁶ and head trauma⁹⁷. There is also evidence that the most deprived sections of the population spend a greater proportion of their lives with a limiting illness or disability⁹⁸. In orthopaedic surgery, social deprivation has been shown to correlate with high energy lower limb trauma⁹⁹, Perthes disease¹⁰⁰ and the outcome after total hip arthroplasty¹⁰¹. A small number of studies have identified a relationship between social deprivation and fracture patterns in children^{102, 103}, male adolescents⁸³ and young male adults¹⁰⁴. In older adult groups a relationship has been identified between deprivation and fractures of the proximal femur^{105, 106}, tibial diaphysis¹⁰⁷ and hand^{108, 109}. A recent study documented the correlation between social deprivation and fall-related fractures in Edinburgh adults¹¹⁰ but the analysis of all commonly encountered fractures in a defined population has not previously been attempted.

1.4 The aims and objectives of this thesis

This introductory section has outlined the importance of epidemiological data, and has discussed the difficulties that researchers must address in designing and implementing fracture epidemiology studies. A review of the currently available adult fracture literature has identified substantial variation between studies, particularly concerning the incidence of adult fractures. In addition, recent literature has explored the influence of socioeconomic deprivation on the patterns of fractures encountered. The three main aims of this thesis incorporate the issues highlighted in the introduction, and are dealt with in the following three sections.

Section 2: A comparative study of two research methodologies.

The aim of Section 2 of this thesis is to investigate the effect of employing different research methods on the number and patterns of fractures reported. A longitudinal comparative study was designed to measure the ascertainment and recording of fractures in the emergency department of the Royal Infirmary of Edinburgh and that of the orthopaedic trauma unit of the same institution.

Hypothesis. The use of numerator fracture data obtained from emergency department sources leads to a falsely elevated number of adult fractures encountered, when compared with orthopaedic trauma unit sources.

Objective 1. To test the above hypothesis, and to determine the direction and magnitude of any observed difference.

Objective 2. To identify predictors of emergency department diagnostic accuracy in terms of patient age, patient gender, injury type, fracture type, and the seniority of the referring emergency clinician.

Section 3: A longitudinal cohort study.

The aim of Section 3 of this thesis is to appreciate and document the range and variation of adult fracture patterns that exists in the Edinburgh population. Adult fracture data were prospectively collected for a twelve month period.

Hypothesis. The complete spectrum of upper limb, lower limb and pelvic fractures affecting adult patients is encountered at the Royal Infirmary of Edinburgh.

Objective 1. To systematically and prospectively collect all adult fractures presenting to the orthopaedic trauma unit of the Royal Infirmary of Edinburgh.

Objective 2. To determine the injury mode and patient characteristics associated with different fracture types.

Objective 3. To compare the findings of this study of adult fracture patterns with previous published studies from the same institution.

Section 4: The effect of socioeconomic deprivation.

The aim of Section 4 of this thesis is to explore whether an association exists between deprivation, as measured by the Scottish Index of Multiple Deprivation, and the incidence of adult fractures in Edinburgh. The degree of socioeconomic deprivation suffered by each patient identified in Section 3 was analysed.

Hypothesis. The incidence of fractures of the upper limb, lower limb and pelvis is higher in patients from deprived areas than those living in affluent areas.

Objective 1. To calculate the incidence of adult fractures in Edinburgh according to population deprivation deciles, and determine if a correlation exists.

Objective 2. To calculate the socioeconomic deprivation fracture ratios for the individual adult fracture types and the injury modes involved.

SECTION 2: A COMPARATIVE STUDY OF TWO RESEARCH METHODOLOGIES

Aim. To investigate the effect of employing different research methods on the number and patterns of fractures reported.

Hypothesis. The use of numerator fracture data obtained from emergency department sources leads to a falsely elevated number of adult fractures encountered, when compared with orthopaedic trauma unit sources.

Objective 1. To test the hypothesis that a difference exists between the numerator fracture data gathered in the emergency department, and the numerator data gathered by the orthopaedic services.

Objective 2. To identify predictors of emergency department diagnostic accuracy in terms of patient age, patient gender, injury type, fracture type, and the seniority of the referring emergency clinician.

2.1 Patients and methods

All adult patients presenting to the emergency department (ED) of the Royal Infirmary of Edinburgh (RIE) with subsequent onward referral to the orthopaedic trauma unit (OTU) fracture clinic were prospectively recorded from July 2007 to June 2008. During this time, the population served by the RIE was 545,081 persons aged 15 years or older (Table 2.1). This figure represented the mid-2007 population estimate, provided by General Register Office for Scotland (GROS), and was based upon Scottish census data¹¹¹.

Age group (yrs)	Men (n)	Women (n)
15-19	19,969	19,241
20-24	26,231	28,482
25-29	27,304	27,727
30-34	22,991	23,228
35-39	23,681	24,812
40-44	23,414	25,348
45-49	21,896	23,361
50-54	19,464	19,904
55-59	18,190	19,313
60-64	15,721	16,996
65-69	12,018	14,031
70-74	10,586	13,216
75-79	8376	11,880
80-84	5403	9282
85-89	2827	5934
90+	1036	3219
All	259,107	285,974

Table 2.1 The age and gender characteristics for the adult population, aged 15 years or older, served by the Royal Infirmary of Edinburgh (n=545,081). Data were obtained from the General Register Office for Scotland, and represent the mid-2007 population estimate based upon Scottish census data¹¹¹.

Patients with fractures and other injuries requiring immediate admission were reviewed by the ED and OTU clinicians simultaneously, and were therefore deemed unsuitable for inclusion in this study (whose primary objective was aimed at identifying a diagnostic discrepancy). In contrast, patients requiring outpatient OTU treatment were rarely reviewed by the OTU doctor prior to fracture clinic attendance, and were therefore deemed suitable for inclusion. In order to pick up possible misdiagnoses, all fracture and non-fracture referred injury types were included in the analysis.

All patients in Edinburgh aged less than 13 years and a proportion of those aged less than 15 years were treated at a separate children's hospital. For this reason, only patients aged 15 years or older were chosen for inclusion in the study. Patients residing outwith the defined catchment area of the RIE and those referred from other institutions were excluded. All patient records in the ED were held electronically. This system was accessed and reviewed as required. Details of fracture clinic review were also held electronically on a separate system. Patients for whom no ED notes or fracture clinic notes could be obtained were excluded, as were those for whom the grade of referring ED clinician was unclear, or not recorded. Patients who failed to attend fracture clinic or chose to cancel their appointment (*i.e.* those lost to follow up) were also excluded.

Injury	Criteria	Examples
Fracture	Axial / appendicular skeletal fracture; stress / dental fractures excluded	Carpus; distal radius; humerus diaphysis <i>etc.</i>
Dislocation	Traumatic dislocation / subluxation	ACJ; ankle; elbow; finger; patella; glenohumeral
STI	Bruising / muscular / ligamentous injury in the absence of fracture	STI ankle; knee; shoulder; wrist
Rupture	Musculotendinous / ligamentous rupture; joint dislocations excluded	Achilles; biceps tendon; EPL; quadriceps muscle; UCL
Wounding	Lacerations / crush injury in the absence of fracture	Any wound not suitable for ED management
Other	All other referrals	Soft tissue FB / infection; post-op pain; symptomatic hardware <i>etc.</i>

Table 2.2 The classification of injury type sustained by the adult population of Edinburgh. (*STI* = soft tissue injury; *ACJ* = acromioclavicular joint; *EPL* = extensor pollicis longus; *UCL* = ulnar collateral ligament of the thumb; *ED* = Emergency Department; *FB* = foreign body).

Classification of injury

The age and gender of each patient referred to fracture clinic were recorded. ED diagnostic data were obtained from the accompanying electronic patient record. Details of the ED attendance, clinical examination, provisional diagnosis and reason for referral were noted.

The injury type suffered by each patient was defined according to the criteria presented in Table 2.2 (previous page). Skeletal fractures were further divided into broad anatomical types according to the criteria set out in Table 2.3.

Fracture type	Criteria
<i>Upper limb</i>	
Carpus	all bones of the carpus
Clavicle	
Distal humerus	
Distal radius	
Distal ulna	without distal radius fracture
Finger	incl. Thumb
Forearm diaphysis	radius, ulna or both bones
Humeral diaphysis	
Metacarpus	metacarpals
Proximal humerus	
Proximal radius	without injury to the ulna
Proximal radius & ulna	
Proximal ulna	without injury to the radius
Scapula	
<i>Lower limb</i>	
Ankle	
Calcaneus	
Distal femur	
Distal tibia	incl. Associated distal fibula fractures
Femoral diaphysis	
Fibula	without injury to ankle
Metatarsus	metatarsals
Midfoot	all midfoot bones
Patella	
Proximal femur	
Proximal tibia	incl. Associated proximal fibula fractures
Sesamoid	
Talus	
Tibial diaphysis	
Toe	
<i>Axial skeleton</i>	
Pelvis	acetabulum, sacrum and innominate bones
Spine	cervical spine only

Table 2.3 The criteria used to classify fractures of the upper limb, lower limb and axial skeleton into fracture types.

Data handling

The grade of the referring ED clinician was recorded for each case. Patients attending the ED were reviewed and referred by a number of clinicians, including specialist nurse practitioners (NP), junior grade doctors (SHO / FY2 / ST1-2), middle grade doctors (SpR / ST3-6) or consultant grade doctors (Cons). In cases where the patient had been reviewed by a number of ED clinicians prior to referral, the grade of the most senior clinician was

recorded. In cases where the OTU doctor had been asked to review the patient prior to referral, the grade was recorded as 'OTU'.

The final OTU diagnosis was made by the OTU doctor in fracture clinic, with or without the additional information provided by the radiology report of accompanying plain radiographs. In cases where the OTU diagnosis remained unclear pending further review or imaging, recording of the definitive diagnosis was deferred until such time as the diagnosis could be confidently made.

In order to test the hypothesis that a difference was present between fracture ascertainment in the ED and fracture ascertainment in the OTU, a *correct* ED diagnosis (true positive) was defined as one where both the injury type and fracture type agreed with the final OTU diagnosis. Any diagnostic discrepancy was deemed an *incorrect* diagnosis (false positive). In particular, when the ED diagnosis of 'fracture' was correct, but the fracture type was incorrectly diagnosed, this was also deemed a false positive. The recording of true and false negatives was not possible because uninjured patients were not referred for OTU assessment.

Statistical analyses

A 12 month sample of convenience was utilised. For the purposes of statistical analyses, multiple events (multiple injuries at presentation; recurrent injury in the same patient over time) were treated as distinct entities.

Primary research objective

Continuous data were presented in terms of the median and interquartile range (IQR). Median values between groups were compared using the Mann-Whitney U test. Groups of categorical variables were compared using the Chi square test, with the addition of Yates' correction for 2x2 contingency tables. Fisher's exact test was preferred when the number of cases was less than five. A two-tailed p-value of <0.05 was considered statistically significant. The positive predictive value (PPV) of an ED diagnosis was calculated by dividing the number of true positive (TP) diagnoses by the number of true positive plus false positive (FP) diagnoses, expressed as a percentage:

$$PPV = TP / (TP + FP) \times 100$$

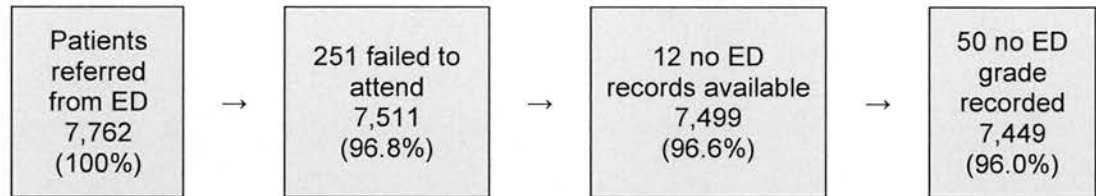
Secondary Research Objective

In order to investigate the potential effect of patient age, patient gender, injury type, fracture type, and the grade of referring ED clinician on the chance of a correct diagnosis, logistic regression analyses were performed. Only those variables that were nearly significant (<0.10) or significant (<0.05) after univariate analysis were entered into the regression models. Logistic regression was performed to determine the best predictors of a correct ED injury type diagnosis, and then more specifically a correct ED fracture type diagnosis. These models produced a statistic called the $Exp(B)$ along with the accompanying 95% confidence interval. The $Exp(B)$ represents the odds ratio for each of the independent variables; *i.e.* the change in odds of being in one of the dependent categories of outcome when the value of a predictor variable increases by one unit. For example, the $Exp(B)$ for the variable *gender* is the odds of being in the *correct diagnosis* category when the patient gender is male [1] rather than female [0]. The $Exp(B)$ for a continuous variable such as *age* is the odds of being in the *correct diagnosis* category with each sequential increase in age by one year.

2.2 Results

Patients

During the 12 month study period 7,762 patients were referred from the RIE ED to the OTU fracture clinic. Two hundred and fifty one patients either cancelled their appointment or failed to attend for review. In 12 cases no ED records were available. In 50 cases the grade of the referring ED clinician was unclear. The resultant patient pathway is summarised in the flow diagram:



Primary Research Objective

After exclusions, 7,449 patients had an ED diagnosis and OTU diagnosis available for comparison. The overall PPV for an ED diagnosis was 78.0% (5,811 true positives and 1,638 false positives). Figure 2.1 shows the age distribution of patients in each category. Patients with a false positive diagnosis were significantly younger ($p < 0.001$).

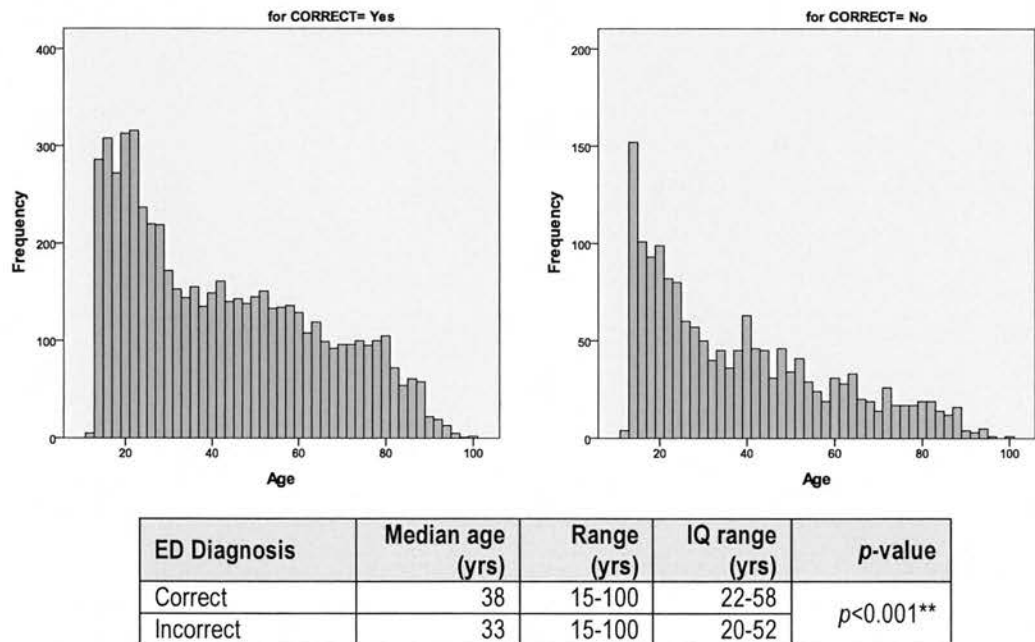


Figure 2.1 The age distribution of patients referred from the emergency department to fracture clinic, with correct and incorrect diagnoses. ** MWU test.

Male patients accounted for 4,127 (55.4%) of 7,449 ED referrals (Table 2.4). The PPV of a correct ED diagnosis was significantly higher in men than in women.

	Men	Women	p-value
Total (n)	4,127	3,322	p=0.023*
Correct (n)	3,260	2,551	
Incorrect (n)	867	771	
PPV (%)	79.0	76.8	

Table 2.4 The total number of male and female patients receiving a correct or incorrect diagnosis from the emergency department, prior to referral to the fracture clinic. The positive predictive value (PPV) is also shown. *Chi square test.

The PPV of a correct diagnosis was highest when the patient had been reviewed by the OTU doctor in the ED (Table 2.5). However, the OTU doctor referred the fewest number of patients. Senior ED doctors were more likely to refer a patient with a correct diagnosis than junior clinicians (SHOs and NPs), although junior ED clinicians were responsible for the majority of referrals to the OTU (n=5,620, 75.4%).

	OTU clinician	Cons	SpR / ST 3+	SHO / ST 1-2	NP	All grades	p-value
Total (n)	250	437	1,142	2,195	3,425	7,449	p<0.001*
Correct (n)	234	362	921	1,677	2,617	5,811	
Incorrect (n)	16	75	221	518	808	1,638	
PPV (%)	93.6	82.8	80.6	76.4	76.4	77.5	

Table 2.5 The positive predictive value (PPV) of a correct emergency department diagnosis, according to grade of referring emergency department clinician, arranged in order of decreasing diagnostic accuracy. (OTU = orthopaedic trauma unit; Cons = consultant; SpR/ST 3+ = registrar; SHO/ST 1-2 = senior house officer; NP = nurse practitioner). *Chi square test.

Seventeen patients were referred to fracture clinic with an ED diagnosis of soft tissue wounding, and all had been correctly diagnosed (Table 2.6).

	Wounds	STI	Dislocation	Rupture	Fracture	Other	p-value
Total (n)	17	854	464	172	5,695	247	p<0.001*
Correct (n)	17	841	429	142	4,204	182	
Incorrect (n)	0	13	35	30	1,491	65	
PPV (%)	100.0	98.5	92.4	82.6	73.8	73.7	

Table 2.6 The positive predictive value (PPV) of a correct emergency department diagnosis, according to the injury type diagnosis given by the referring emergency department clinician, arranged in order of decreasing diagnostic accuracy. (STI = soft tissue injury). *Chi square test.

Musculotendinous rupture was diagnosed in 172 patients, but in 30 patients the OTU diagnosis differed from this. The three commonest rupture final diagnoses were Achilles or gastrocnemius complex (n=69), extensor digitorum in the fingers (n=66) and ulnar collateral ligament of the thumb (n=5). Of note, patients with extensor mechanism ruptures of the knee were all admitted to the OTU for operative treatment. Where a diagnostic discrepancy was apparent, this was most commonly due to referred ruptures of the Achilles' tendon receiving an OTU diagnosis of soft tissue injury rather than rupture (Table 2.7).

OTU Diagnosis		ED Diagnosis (n)						All
		Fracture	Dislocation	STI	Rupture	Wounds	Other	
Fracture	Site correct	4,204	22	11	2	0	65	4,434
	incorrect	130						
Dislocation		1	429	1	0	0	0	431
STI		1,356	12	841	27	0	0	2,236
Rupture		1	0	1	142	0	0	144
Wounding		0	0	0	0	17	0	17
Other		3	1	0	1	0	182	187
All		5,695	464	854	172	17	247	7,449

Table 2.7 A comparison of emergency department (ED) diagnoses with relation to the final orthopaedic trauma unit (OTU) diagnoses. The pink shaded cells represent true positive ED diagnoses, and the remainder represent false positive diagnoses. (STI = soft tissue injury).

'Other' diagnoses accounted for 247 referred cases, and contained a wide variety of conditions that did not meet the inclusion criteria for another injury type category. Commonly encountered cases included suspected soft tissue infection, post-operative pain and swelling, acute joint or limb pain in the absence of trauma, exacerbations of arthritis and cases of symptomatic hardware.

Traumatic joint dislocations were diagnosed more frequently and more accurately by the ED clinician (PPV 92.4% vs. 82.6%) than musculotendinous rupture. The three commonest dislocation final diagnoses were those affecting the glenohumeral joint (n=229), fingers or thumb (n=90) and acromioclavicular joint (n=44).

The ED diagnosed 854 soft tissue injuries with a PPV of 98.5%. The majority of soft tissue injury referrals were knee injuries (n=655) that had been directed towards dedicated 'acute knee clinics'. Soft tissue injury to the shoulder (n=72) and ankle (n=23) were also commonly encountered.

In one year, three-quarters of ED patient referrals to the OTU fracture clinic were for cases of suspected fracture. Of 5,695 patients referred with a fracture, 26.2% were attributed a false positive diagnosis. A small number had been miscoded as fractures from a different anatomical region. The majority of false positive diagnoses received an OTU diagnosis of soft tissue injury. Eight fracture subtype diagnoses were significantly better diagnosed compared with 'all fractures', while a further eight were diagnosed with far less accuracy (Table 2.8).

Fracture subtype	Total (n)	Correct (n)	Incorrect (n)	PPV (%)	p-values*
Radius & ulna	2	2	0	100.0	0.400
Ulna diaphysis	22	21	1	95.5	0.021
Clavicle	283	261	22	92.2	<0.001
Toe	111	102	9	91.9	<0.001
Proximal humerus	374	342	32	91.4	<0.001
Humerus diaphysis	31	27	4	87.1	0.092
Metacarpus	715	614	101	85.9	<0.001
Radius diaphysis	7	6	1	85.7	0.474
Metatarsus	418	358	60	85.6	<0.001
Distal radius	1,079	895	184	82.9	<0.001
Finger	788	623	165	79.1	<0.001
Ankle	474	364	110	76.8	0.124
Proximal ulna	28	21	7	75.0	0.887
Patella	23	17	6	73.9	0.992
Overall				73.8	
Spine	11	8	3	72.7	0.934
Distal tibia	17	12	5	70.6	0.762
Fibula	40	28	12	70.0	0.581
Scapula	32	20	12	62.5	0.144
Proximal radius	342	208	134	60.8	<0.001
Distal ulna	54	32	22	59.3	0.014
Calcaneus	27	14	13	51.9	0.009
Proximal tibia	29	15	14	51.7	0.007
Distal femur	4	2	2	50.0	0.278
Pelvis	8	4	4	50.0	0.125
Proximal femur	8	4	4	50.0	0.125
Talus	22	11	11	50.0	0.011
Tibia diaphysis	4	2	2	50.0	0.278
Distal humerus	30	12	18	40.0	<0.001
Midfoot	45	18	27	40.0	<0.001
Carpus	666	161	505	24.2	<0.001
Proximal radius & ulna	0	0	0	0.0	-

Table 2.8 The number of correct and incorrect emergency department (ED) fracture subtype diagnoses attributed to patients referred from the ED to fracture clinic. The positive predictive value (PPV) for each fracture subtype is also shown. The pink shaded area illustrates the overall PPV of all ED fracture subtypes. The blue shaded areas represent the subtype diagnoses with a statistically significant greater or lesser PPV than 'Overall'. *Chi square tests.

Secondary Research Objective

In order to identify predictors of ED diagnostic accuracy, all independent variables that had proven nearly significant (<0.10) or significant (<0.05) after univariate analysis were entered into logistic regression equations. These analyses identified the independent variables that best explained the variation in the dependent outcome variable (*i.e.* correct vs. incorrect ED diagnosis) while taking confounding into account. The first model identified predictors of a correct ED injury type diagnosis, while the second identified predictors of a correct ED fracture type diagnosis. The results are shown in Tables 2.9 and 2.10.

Variable	Exp(B)	95% CI for Exp(B)		p-values*
		Lower	Upper	
Age	1.01	1.01	1.02	<0.001
Male gender	1.28	1.13	1.45	<0.001
Consultant	1.31	1.00	1.70	0.048
SHO	0.85	0.75	0.96	0.009
Ortho	4.31	2.56	7.24	<0.001
ED Dislocation Dx	0.16	0.08	0.30	<0.001
ED Fracture Dx	0.04	0.02	0.07	<0.001
ED Other Dx	0.03	0.02	0.06	<0.001
ED Rupture Dx	0.06	0.03	0.12	<0.001

Table 2.9 Independent variables predictive of a correct emergency department *injury type* diagnosis, identified after logistic regression analysis. (Dx = diagnosis). *Chi square tests.

Variable	Exp(B)	95% CI for Exp(B)		p-values*
		Lower	Upper	
Age	1.01	1.01	1.02	<0.001
Male gender	1.17	1.01	1.36	0.037
SHO	0.76	0.66	0.88	<0.001
Ortho	3.60	2.00	6.48	<0.001
Calcaneus	0.37	0.17	0.81	0.013
Carpus	0.12	0.10	0.16	<0.001
Clavicle	4.65	2.91	7.45	<0.001
Distal humerus	0.20	0.09	0.44	<0.001
Distal radius	1.63	1.29	2.07	<0.001
Distal ulna	0.53	0.29	0.94	0.030
Finger	1.45	1.14	1.86	0.003
Metacarpus	2.46	1.86	3.24	<0.001
Metatarsus	2.31	1.67	3.20	<0.001
Midfoot	0.25	0.13	0.46	<0.001
Proximal humerus	3.10	2.07	4.66	<0.001
Proximal radius	0.58	0.44	0.76	<0.001
Proximal tibia	0.35	0.16	0.76	0.008
Toe	4.55	2.25	9.22	<0.001
Ulna diaphysis	7.57	1.01	57.01	0.049

Table 2.10 Independent variables predictive of a correct emergency department *fracture type* diagnosis, identified after logistic regression analysis. *Chi square tests.

SECTION 3: A LONGITUDINAL COHORT STUDY

Aim. To appreciate and document the range and variation of adult fracture patterns that exists in the Edinburgh population.

Hypothesis. The complete spectrum of upper limb, lower limb and pelvic fractures affecting adult patients is encountered at the Royal Infirmary of Edinburgh.

Objective 1. To systematically and prospectively collect all adult fractures presenting to the orthopaedic trauma unit of the Royal Infirmary of Edinburgh.

Objective 2. To determine the injury mode and patient characteristics associated with different fracture types.

Objective 3. To compare the findings of this study of adult fracture patterns with previous published studies from the same institution.

3.1 Patients and methods

All inpatients and outpatients presenting to the OTU of the RIE with an acute fracture were prospectively recorded for a 12 month period between 1st July 2007 and 30th June 2008. The hospital serves a defined adult population. The fracture information was gathered by the author (SORT-IT trauma fellow) for the duration of the study. A fracture diagnosis was made by examining each set of radiographs, supplemented where necessary by the radiology report and documented clinical findings.

Fracture definition, classification and ascertainment – the ‘Numerator’

All acute fractures of the upper limbs, lower limbs, and pelvis were included in the study. Severe hand trauma requiring complex reconstruction and / or flexor tendon repair was treated at a separate institution in West Lothian, but the majority of other hand fractures were treated at the OTU. Hand fractures were therefore chosen for inclusion in the study.

Rib fractures and skull and facial fractures were excluded, as these injuries are not commonly encountered by the OTU in Edinburgh. Maxillofacial injuries are routinely seen and treated at a separate institution in West Lothian. Spinal fractures in Edinburgh have historically been treated by either the OTU or by the neurosurgical services at a separate institution. Many thoracolumbar fractures resulting from low energy trauma in the elderly are treated by general practitioners, and do not come to the attention of the OTU. Therefore the decision was taken to exclude all cervical and thoracolumbar fractures from analysis, largely because of the inability to confidently identify these injuries within the Edinburgh population. Fragility fractures, other pathological fractures and acute periprosthetic fractures were analysed, but stress fractures were excluded. Acute fractures occurring in association

with cases of pre-hospital death were excluded, as there was no reliable method for ensuring the presence of skeletal injury or indeed the types of fractures suffered by these individuals. All fractures meeting the inclusion criteria were recorded and categorised by fracture type, as shown in Table 3.1.

Fracture type	Criteria
<i>Upper limb</i>	
Carpus	all bones of the carpus
Clavicle	
Distal humerus	
Distal radius	
Distal ulna	without distal radius fracture
Finger	incl. thumb
Forearm diaphysis	radius, ulna or both bones
Humeral diaphysis	
Metacarpus	metacarpals
Proximal humerus	
Proximal radius	without injury to the ulna
Proximal radius & ulna	
Proximal ulna	without injury to the radius
Scapula	
<i>Lower limb</i>	
Ankle	
Calcaneus	
Distal femur	
Distal tibia	incl. associated distal fibula fractures
Femoral diaphysis	
Fibula	without injury to the ankle
Metatarsus	metatarsals
Midfoot	all midfoot bones
Patella	
Proximal femur	
Proximal tibia	incl. associated proximal fibula fractures
Sesamoid	
Talus	
Tibial diaphysis	
Toe	
<i>Axial skeleton</i>	
Pelvis	acetabulum, sacrum and innominate bones

Table 3.1 The criteria used to classify fractures of the upper limb, lower limb and axial skeleton into fracture types.

Fractures were further classified according to the AO comprehensive long bone classification system, since modified by the OTA, and shown at the Appendix¹⁴. Where appropriate, fracture types were also classified according to the various fracture-specific systems in common usage (Table 1.1). Open fractures were classified according to the criteria first described by Gustilo and Anderson in 1976¹¹², further modified by Gustilo in 1984¹¹³, and shown in Table 3.2 (next page).

	Criteria
Grade 1	Clean wound of less than 1cm in length
Grade 2	Wound larger than 1cm, but less than 10cm, without extensive soft tissue damage
Grade 3	Wound associated with extensive soft tissue damage, including: Open segmental fracture; traumatic amputation; gunshot injuries; farmyard injuries; all 'high energy' trauma; fractures more than 8 hours old
3a	Adequate periosteal and soft tissue coverage
3b	Significant periosteal stripping and overlying soft tissue loss
3c	Associated vascular injury, requiring repair

Table 3.2 The Gustilo criteria, used to classify open fractures of the long bones of the appendicular skeleton.

The OTU deals with all acute orthopaedic injuries (except severe hand trauma and neurosurgical trauma) in a captive adult population, and so the ascertainment of fracture cases is high. Several local institutions offer private medical care, but are ill-equipped to deal with acute fractures and are therefore not utilised in this way. The OTU is a tertiary referral centre for orthopaedic trauma, receiving fracture referrals from the ED, local general practitioners, local minor injuries units, as well as occasional referrals from other orthopaedic centres. The OTU is ideally placed to identify acute fractures that present to the health care services in Edinburgh.

The correct ascertainment of acute fractures for epidemiological research relies on the ability of researchers to interpret plain radiographs and alternative imaging modalities. In this study, all radiographs were examined by the author (an orthopaedic trauma fellow). In cases where the diagnosis was not clear from initial radiographs, further information was obtained from the accompanying radiology report, the referring clinicians' examination findings, the orthopaedic clinicians' examination findings, and the results of further imaging.

Population at risk – the 'Denominator'

All adult patients in the City of Edinburgh, Midlothian and East Lothian council areas receive inpatient and outpatient orthopaedic care at the OTU. Patients residing outwith this catchment area (as determined by address and postal code) were excluded from analysis, but Edinburgh residents injured elsewhere and followed up at the OTU were included. Orthopaedic care for West Lothian residents is shared with a second institution, and therefore all West Lothian residents were excluded from the study. Children in Edinburgh are treated at a separate paediatric institution. The threshold for transfer to the adult hospital is 13 years of age, but a number of 13 and 14 year olds are known to be treated at the paediatric hospital. This study was therefore limited to patients aged 15 years or older.

Edinburgh population data for the period of study was obtained from the General Register Office for Scotland (GROS). The last UK census was carried out in 2001, and the GROS annually calculates mid-year population estimates based upon these data. The starting point for mid-year estimates is the resident population on 30 June in the previous year. Data on births, deaths and migration trends for the preceding 12 month period are taken into account. A full and detailed account of the methodology used by GROS to produce the annual mid-year population estimates is available on the GROS website¹¹⁴. For this study the mid-2007 population estimate was used to define the population at risk¹¹¹.

Causation

The circumstances surrounding the occurrence of acute fractures were recorded, and an attempt was made to categorise these as the *mode* of injury. The term *mechanism* of injury was deliberately avoided, as it is seldom possible to accurately determine the precise mechanism by which a fracture is sustained (*e.g.* torsional stress, axial loading *etc.*). Although the categories were not mutually exclusive (*e.g.* cycling as a sport *vs.* cycling as a road user), the criteria outlined in Table 3.3 were adhered to. Only patients surviving long enough to be referred from the ED for orthopaedic treatment were included. Patients noted to be ‘deceased on arrival’ at the RIE, or who died in the ED, were not included.

Mode of injury	Criteria
Simple fall	caused by a fall from a standing height, including twisting injuries, falls down two or fewer stairs
Fall down stairs	caused by a fall down three or more stairs, including twisting injuries
Fall from a height	caused by a fall from a height of six feet or more, excluding falls down multiple stairs.
Sports-related	injury sustained during sports participation or other athletic activity
Road traffic accident	injury to a vehicle occupant, pedestrian, cyclist, motorcyclist resulting from an accident on a road or highway
Direct blow / assault / crush injury	caused by direct or indirect violence, including fighting / assault, punch injury, any sort of crush injury
Nil / spontaneous	injury with no apparent causal mechanism (<i>i.e.</i> pathological fracture caused as the result of physiological loading of abnormally weakened bone)
Other	encompassing all other recorded injury modes, including cases where the mode was unknown due to amnesia for events, alcohol intoxication or cognitive impairment

Table 3.3 The criteria used to determine and classify the mode of injury responsible for acute fractures in the Edinburgh adult population.

Multiplicity

For the purposes of data analysis and statistical testing, multiple events were treated according to the following criteria:

- A single fracture occurring in any adult patient was recorded as ‘one fracture, one patient’.
- *Recurrent fracture* episodes in the same patient over time were recorded as ‘two fractures, one patient’, with any subsequent recurrences added accordingly.
- *Multiple fractures* occurring in any adult patient at the same time were considered as separate entities if they conformed to the criteria in Table 3.1. The analysis of multiple fractures only included these fracture types. Associated fractures of the ribs, skull and facial bones and spinal fractures were not recorded or included in the analysis.
- Two or more fractures of the fingers or toes were recorded as ‘one fracture’.
- Segmental fractures of long bones were recorded as ‘one fracture’.
- Ankle fractures involving both medial and lateral malleoli were considered as ‘one fracture’ as were ankle fractures involving the proximal fibula.
- Complex fractures of multiple metatarsals (including Lisfranc fracture dislocations) and fractures of multiple metacarpals were recorded as ‘two fractures’.
- Complex fractures of the midfoot, hindfoot and carpus were similarly recorded as ‘two fractures’, even if more than two bones were involved.
- Fractures involving the pelvic ring were considered as ‘one fracture’ even if the ring was disrupted in two or more places. However, associated fractures of the pelvic ring *and* acetabulum were considered as ‘two fractures’.

Statistical analysis

Microsoft Excel 2007 (Microsoft Corp, Redmond, Washington) and SPSS version 18.0 (SPSS, Chicago, Illinois) were used to undertake statistical analyses. Data were checked for normality using the Kolmogorov-Smirnov test. Continuous data were presented in terms of the median, range (R) and interquartile range (IQR) if asymmetrically distributed, and the mean and standard deviation (SD) if symmetrically distributed.

Median values between groups were compared using the Mann-Whitney U (MWU) test for two groups, or the Kruskal-Wallis (KW) test for three or more groups. The *t*-test was used to compare means. Groups of categorical variables were compared using the Chi square test, with the addition of Yates’ correction for 2x2 contingency tables. Fisher’s exact test was

preferred when the number of cases was less than five. A two-tailed p -value of <0.05 was considered statistically significant.

Fracture incidence was calculated as the number of fractures per 10,000 head of population per year ($n/10,000/\text{yr}$), unless otherwise stated. The 95% confidence interval (CI) around the rates was estimated using the cumulative Poisson distribution.

3.2 Overall fracture incidence

Population at risk

According to Scottish government sources, the Edinburgh adult population from 1st July 2007 to 30th June 2008 totalled 545,081. This total represented the mid-year population estimate for 2007 and was adjusted from Scottish census results in 2001. Women outnumbered men in all but the very youngest age group category (Table 3.4). The ratio of women to men was 1.1:1 overall, but gradually increased to 3.1:1 in patients aged 90 years or more. The age- and gender-related distribution of the Edinburgh population is shown diagrammatically in Figure 3.1 (next page).

Age group (yrs)	Men (n)	Women (n)
15-19	19,969	19,241
20-24	26,231	28,482
25-29	27,304	27,727
30-34	22,991	23,228
35-39	23,681	24,812
40-44	23,414	25,348
45-49	21,896	23,361
50-54	19,464	19,904
55-59	18,190	19,313
60-64	15,721	16,996
65-69	12,018	14,031
70-74	10,586	13,216
75-79	8,376	11,880
80-84	5,403	9,282
85-89	2,827	5,934
90+	1,036	3,219
All	259,107	285,974

Table 3.4 The age- and gender-related characteristics for the adult population, aged 15 years or older, served by the Royal Infirmary of Edinburgh (n=545,081). Data were obtained from the General Register Office for Scotland¹¹¹, and represent a mid-year population estimate for 2007.

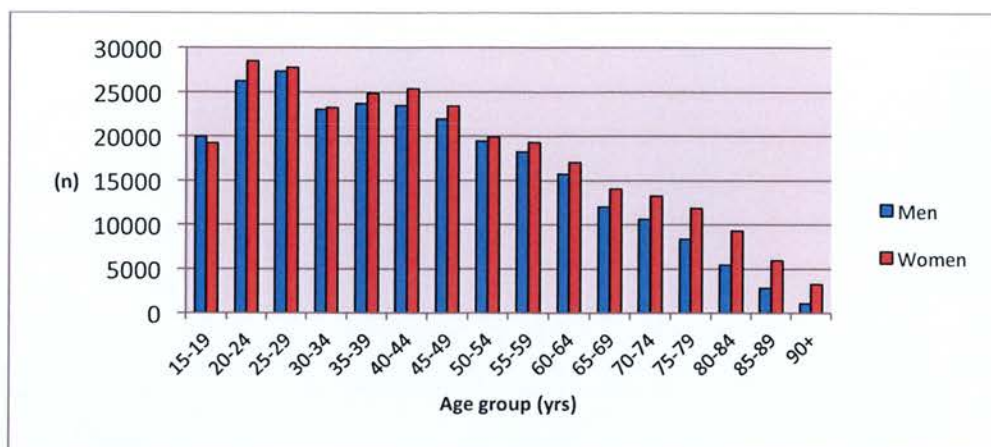


Figure 3.1 The age- and gender-related distribution of adults, aged 15 years or older, resident in Edinburgh (City of Edinburgh, Midlothian and East Lothian). Data were obtained from the General Register Office for Scotland¹¹¹, and represent a mid-year population estimate for 2007 (n = 545,081).

Fracture incidence

During the study period 6,846 fractures were sustained by 6,307 adults. The median age of all patients was 51 years (IQR, 28-74 yrs) with a range from 15 years to 102 years. There were 2,988 men with a median age of 34 years (IQR, 22-53 yrs). Male patients suffered a total of 3,278 fractures (1.10 fractures per patient). There were 3,319 women with a median age of 66 years (IQR, 47-80 yrs) who suffered 3,568 fractures (1.08 fractures per patient).

Table 3.5 shows the age and gender characteristics of patients presenting with a single fracture, with several fractures from the same episode (multiple fractures), or with more than one fracture episode (recurrent fractures). Multiple fractures were more common in men while recurrent fractures were seen more often in older women.

Fracture group	Patients (n)	Fractures (n)	Age in yrs (median, IQR)	Gender ratio (M:F, %)
1 only	5,837	5,824	51 (28-74)	47:53
2 only	308	630	53 (28-74)	54:46
3 only	30	84	59 (35-77)	60:40
4+ only	15	64	43 (27-48)	73:27
Recurrent episodes	117	244	69 (33-85)	43:57
Total	6,307	6,846	51 (28-74)	47:53

Table 3.5 The age- and gender-related characteristics of adult fracture patients in Edinburgh presenting with one fracture, multiple fractures or recurrent fractures.

The overall fracture incidence and the age- and gender-related incidences are shown in Table 3.6 and Figure 3.2. The overall incidence for men and women was similar but the distribution was quite different. All previous studies of adult fracture incidence have demonstrated a bimodal distribution in men and a unimodal distribution in women^{85, 86, 88, 89}, and this pattern has been replicated in Figure 3.2.

Age group (yrs)	Male (n/10,000/yr)	Female (n/10,000/yr)	Overall (n/10,000/yr)
15-19	250.9	60.3	157.4
20-24	165.5	51.3	106.0
25-29	126.7	45.4	85.8
30-34	103.1	49.1	75.9
35-39	95.0	46.8	70.3
40-44	89.7	54.4	71.4
45-49	78.6	59.9	68.9
50-54	76.6	98.0	87.4
55-59	58.8	115.5	88.0
60-64	74.4	148.9	113.1
65-69	74.9	187.4	135.5
70-74	80.3	205.8	150.0
75-79	123.0	265.2	206.4
80-84	188.8	391.1	316.6
85-89	233.5	547.7	446.3
90+	521.2	689.7	648.6
All	126.5	124.8	125.6

Table 3.6 The age-adjusted incidences of acute fractures in Edinburgh adults by five-year patient age group, according to gender. The overall incidences are also shown.

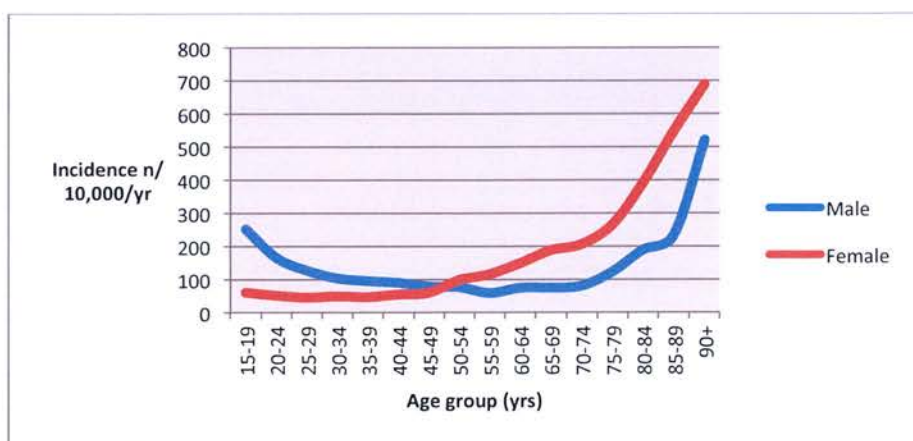


Figure 3.2 The age-related distribution of fractures (n = 6,846) in adult men and women in Edinburgh.

The highest fracture rates occurred in men aged between 15 and 19 years, and then much later in men aged 90 years or more. In women the distribution was unimodal as fracture

incidence increased steadily with age. Peak fracture incidence was seen in elderly female patients (690/10,000/yr, 90+ yrs). Peak fracture incidence in men was lower than this (521/10,000/yr, 90+ yrs), but also affected the oldest patient group. The second peak in elderly male patients is becoming more pronounced as male life expectancy increases and the risk of fracture through osteoporotic bone rises. The lowest fracture incidence was seen in women aged between 25 and 39 years.

Table 3.7 (next page) contains details of all fracture types identified and recorded during the period of study. Upper limb injuries were more common than those of the lower limb, and limb fractures in general far outnumbered those of the pelvis. Overall, male patients outnumbered female patients in 15 fracture types and women predominated in 20 types.

Fracture type	Fractures (n)	Frequency (%)	Patients (n)	Incidence (n/10 ⁴ /yr)	Age in yrs (median, IQR)	Gender (M:F, %)
<i>Upper limb</i>	4,152	60.6	4,031	76.2	45 (25-68)	52:48
Carpus	205	3.0	201	3.8	28 (22-46)	70:30
Clavicle	280	4.1	279	5.1	36.5 (23-59)	71:29
Distal humerus	49	0.7	46	0.8	71.5 (38-83)	35:65
Distal radius	1,124	16.4	1,108	20.6	62 (37-76)	30:70
Distal ulna	34	0.5	33	0.6	44 (24-76)	61:39
Finger	677	9.9	663	12.4	36 (23-50)	65:35
Forearm diaphysis	68	1.0	68	1.2	25.5 (19-54)	78:22
Humeral diaphysis	69	1.0	69	1.3	60 (46-78)	48:52
Metacarpus	737	10.7	682	13.5	25 (20-38)	79:21
Proximal humerus	505	7.3	497	9.3	70 (55-80)	31:69
Proximal radius	266	3.8	255	4.9	43 (28-56)	47:53
Proximal radius & ulna	23	0.4	15	0.4	58 (36-82)	33:67
Proximal ulna	67	1.0	66	1.2	59 (36-75)	47:53
Scapula	50	0.7	49	1.3	51 (35-74)	45:55
<i>Lower limb</i>	2,563	37.4	2,506	47.0	60 (37-80)	41:59
Ankle	630	9.2	627	11.6	50 (31-64)	46:54
Calcaneus	55	0.8	48	1.0	36.5 (23-51.5)	77:23
Distal femur	36	0.5	36	0.7	65 (45-86)	36:64
Distal tibia	56	0.8	54	1.0	40 (27-52.5)	65:35
Femoral diaphysis	96	1.4	96	1.8	75.5 (59.5-85)	44:56
Fibula	29	0.4	29	0.5	39 (26-48)	72:28
Metatarsus	430	6.2	406	7.9	44 (26-60)	37:63
Midfoot	37	0.5	32	0.7	40 (28-58)	44:56
Patella	55	0.8	55	1.0	64 (42-72)	33:67
Proximal femur	821	11.9	809	15.1	83 (76-88)	27:73
Proximal tibia	82	1.2	80	1.5	58 (34-76)	44:56
Sesamoid	1	<0.1	1	<0.1	21	100:0
Talus	33	0.5	33	0.6	33 (23-44.5)	61:39
Tibial diaphysis	78	1.1	77	1.4	31 (22-50.5)	79:21
Toe	124	1.8	123	2.3	33 (22.5-48)	55:45
<i>Axial skeleton</i>	131	2.0	149	2.4	76 (45-85)	40:60
Pelvis	131	2.0	127	2.4	77 (43-86)	28:62
All	6,846	100	6,307	125.6	51 (28-74)	47:53

Table 3.7 The number and frequency of each fracture type, occurring in Edinburgh adults, and identified during the study period. The number, age distribution, and gender ratio of patients affected is also shown.

3.3 Modes of injury

The circumstances surrounding the occurrence of skeletal fracture were referred to as the *mode* of injury, rather than the injury *mechanism*. Eight different modes were recorded, and they are listed in order of decreasing frequency in Table 3.8. The commonest injury modes to affect female patients were those associated with low energy transfer, such as simple falls from a standing height and falls down stairs. Fractures occurring in the apparent absence of a causal mechanism (pathological fractures) also affected women more often than men.

Fractures in men were more commonly the result of higher energy trauma such as sporting injury, road traffic accidents, falls from height, and fights or assaults.

Mode of injury	(n)	(%)	'n' per patient	Age (yrs, IQR)	Gender (M:F, %)	Fracture distribution (%)		
						Upper limb	Lower limb	Pelvis
Simple fall	3,675	53.7	1.07	69 (52-81)	28:72	52.4	45.4	2.2
Sports-related	990	14.5	1.05	25 (19-35)	82:18	76.9	22.3	0.8
Direct blow	885	12.9	1.08	30 (21-44)	76:24	82.9	16.7	0.4
Other	387	5.7	1.07	43 (27-67)	51:49	68.0	31.8	0.2
RTA	361	5.3	1.30	37 (26-50)	77:23	60.7	35.7	3.6
Fall (stairs)	260	3.8	1.12	57 (39-73)	38:62	52.7	45.8	1.5
Fall (height)	249	3.6	1.26	37 (25-48)	77:23	40.6	50.2	9.2
Nil / spont	39	0.6	1.00	68 (61-79)	23:77	25.6	74.4	0.0
All	6,846	100	1.09	51 (28-74)	47:53	60.6	37.4	2.0

Table 3.8 The number and frequency of fractures sustained by the eight modes of injury in the Edinburgh population. The age distribution and gender ratio of affected patients is shown. The distribution between fracture categories for each mode is also given. (RTA = road traffic accident; Nil / spont = no history of trauma, or spontaneous).

Simple falls

The majority (53.7%) of acute fractures in Edinburgh adults occurred as a result of a simple fall. There were 3,675 simple fall fractures in 3,439 patients (1.07 fractures per patient).

The distribution curve for simple fall fractures (Fig. 3.3) matches the 'post wage-earning' curve described by Buhr and Cooke⁸⁴ in 1959, and the type F unimodal older male and female curve proposed by Court-Brown and Caesar⁸⁸ in 2006. The shapes of the male and female curves in Figure 3.3 are virtually identical, but the male curve is shifted to the right by ten to 15 years, suggesting that the predisposing characteristics for simple fall fractures in women are also present in male patients, but at a later stage in life.

Female patients accounted for 72% of all simple fall fracture sufferers, although this is likely to be due to the greater proportion of women in older age groups. However, of the 3,568

acute fractures suffered by women during the study period, 74.4% were caused by a simple fall. In contrast, simple falls accounted for only 31.0% of all fractures in men.

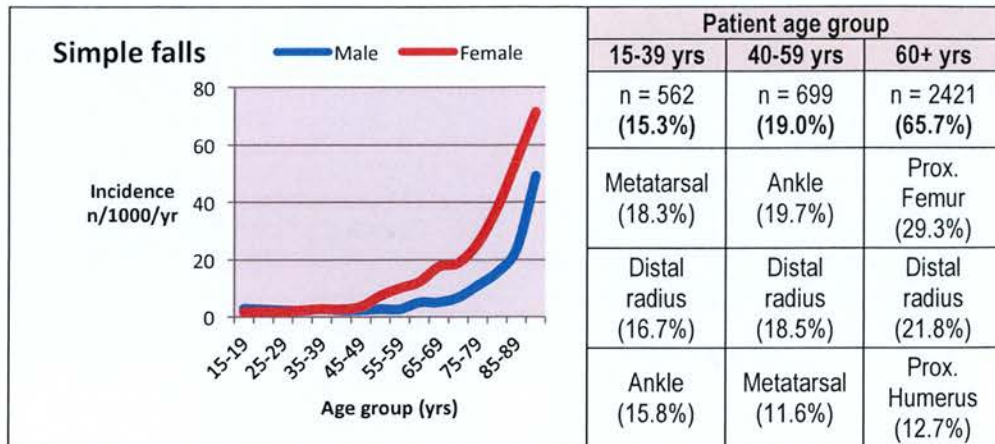


Figure 3.3 The age- and gender-related incidence of fractures occurring in Edinburgh adults, caused by a simple fall. The frequencies of the three most common fracture types, according to three broad patient age groups, are also shown.

In keeping with previous research¹¹⁵⁻¹¹⁷, simple fall fractures became more frequent with advancing patient age. In young adults (15-39 yrs) simple falls accounted for 22.0% of fractures. Between 40 years and 59 years of age, simple falls accounted for 48.2% of injuries. In older adults (60 yrs and older) the frequency of simple fall fractures was 84.4%. With advancing age, certain fracture types were more commonly encountered, and lower limb fractures became more common than those of the upper limb.

Sports-related fractures

Sporting activity was the second most common cause of fractures in Edinburgh adults, accounting for 14.5% of all injuries. A total of 990 fractures were sustained by 941 individuals (1.05 per patient). The distribution curve (Fig. 3.4) for sports fractures shows that young adults were frequently affected. Men were injured more often than women, but this may simply represent a gender difference in sports participation. The curve is type C (according to Court-Brown and Caesar⁸⁸) or L shaped (Buhr and Cooke⁸⁴). Sports-related fractures accounted for 24.6% and 5.1% of fractures in men and women, respectively.

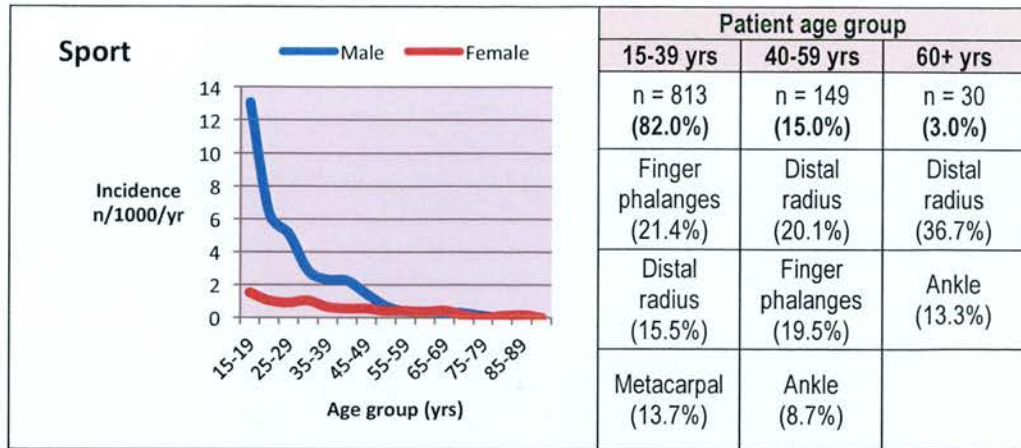


Figure 3.4 The age- and gender-related incidence of fractures occurring in Edinburgh adults, caused by sporting activity. The frequencies of the three most common fracture types, according to three broad patient age groups, are also shown.

The frequency of sports-related fractures decreased sharply with advancing age. Sport accounted for 31.8% of fractures in young adults (15-39 yrs), 10.3% of fractures in older adults (40-59 yrs) and 1.0% of fractures in the oldest adult group (60 yrs or more). Sports fractures most commonly affected the upper limb, in particular the hand and wrist. With advancing age ankle fractures increased in frequency. Sports-related fractures were attributed to 49 sports. For the purposes of data analysis some sports were combined. Thai-boxing, kick-boxing, karate, judo and taekwondo were termed 'martial arts'. Rugby league and rugby union were referred to as 'rugby'. Roller-blading was combined with 'roller-skating'. Indoor and outdoor 'sports climbing' were also combined. Twelve sports (football, rugby, skiing, snowboarding, the cycling disciplines, horse riding, motocross, basketball, martial arts and ice skating) accounted for 82.8% of all sports-related fractures (Table 3.9, next page).

Football was responsible for over one-third of sports-related fractures in Edinburgh adults. The upper limb was more commonly involved (69.8%) than the lower limb (29.9%) or pelvis (0.3%). The commonest upper limb fractures encountered were those of the finger phalanges (n=74), distal radius (n=70), metacarpus (n=29), carpus (24 scaphoid, one triquetrum and one capitate fracture), clavicle (n=20) and proximal radius (n=17). Common fractures of the lower limb included those of the ankle (n=45), metatarsus (n=23) and tibial diaphysis (n=14). In 50% of football-related tibial diaphyseal fractures, the fibula was left intact. There was one avulsion fracture of the pelvic ring: a 15 year old schoolboy suffered an avulsion fracture of the anterior inferior iliac spine.

Sport	(n)	Age (yrs)	Gender ratio (M:F)	Fractures (n)					
				(%)	Upper limb	Lower limb	Pelvis		
Football	351	35.4	27	98:2	245	105	1		
Rugby	144	14.5	22	94:6	119	25	0		
Alpine sports	Skiing	Alpine	30	6.7	41	47:53	25	4	1
		Dry	36		28	61:39	36	0	0
	Snow-boarding	Alpine	25	4.2	28	52:48	23	1	1
		Dry	17		23	76:24	17	0	0
Cycling	BMX	6	10.5	20	100:0	4	2	0	
	Road	25		43	76:24	23	2	0	
	Mountain biking	73		28	92:8	68	4	1	
Horse riding	25	2.6	39	15:85	12	11	2		
Motocross	24	2.4	26	100:0	13	10	1		
Basketball	22	2.2	21	68:32	19	3	0		
Martial arts	22	2.2	27	68:32	14	8	0		
Ice skating	20	2.0	39	25:75	15	5	0		
All sports	990	100	25	82:18	761	222	8		

Table 3.9 The number and frequency of fractures in Edinburgh adults resulting from the top twelve sporting activities. The (median) age and gender ratio of patients involved is shown. For each sport, the distribution of fractures across the appendicular skeleton and pelvis is also shown.

Rugby accounted for 14.5% of fractures. The upper limb was affected 82.7% of the time, with the remainder affecting the lower limb. Upper limb fractures included the finger phalanges (n=40), metacarpus (n=26), clavicle (n=24) and distal radius (n=11). Ankle fractures accounted for 15 of the 25 lower limb fractures.

Skiing and snowboarding accounted for 11% of sports-related fractures. Unlike the majority of sports, approximately equal numbers of men and women were affected. Skiers tended to be older than snowboarders. Fractures suffered whilst skiing or boarding on artificial matting resulted exclusively in upper limb injury, affecting the finger phalanges (n=19), metacarpus (n=13) and distal radius (n=11), presumably resulting from a fall onto the outstretched hand. Alpine skiing and snowboarding resulted in a similar pattern of upper limb injury: fractures of the distal radius (n=17), finger phalanges (n=9) and clavicle (n=8) were encountered. In addition, a number of lower limb fractures were noted: two ankle fractures, one proximal femoral fracture, one tibial plateau fracture and a fibular neck fracture. In addition, two lateral compression pelvic fractures were sustained: one from Alpine skiing and one from Alpine snowboarding.

The cycling disciplines accounted for 10.5% of sports-related fractures. Almost three-quarters of these were sustained from mountain biking, predominantly affecting young men. One-quarter of cycling fractures was suffered by road cyclists; again predominantly men, but with a higher average age. A small number of BMX fractures were suffered by young male adults. During the 12-month period of study, no discernible difference was seen in the patterns of skeletal injury between the disciplines. The majority of fractures affected the upper limb, most likely caused by a fall onto the limb. Fractures of the clavicle (n=23), distal radius (n=15), proximal radius (n=12), metacarpus (n=12) and finger phalanges (n=10) were noted. A number of relatively high energy injuries were seen. One distal tibial fracture resulted from a BMX accident. From mountain biking, one lateral compression pelvic fracture was recorded. From road cycling, one proximal femoral fracture, a femoral diaphyseal fracture and a scapular body fracture were sustained.

In the majority of sports, upper limb fractures outnumber those of the lower limb. However, two sports in this series (horse riding and motocross) were associated with a higher proportion of significant lower limb or pelvic injury. Of the 25 fractures sustained as a result of horse riding, two involved the pelvis (one acetabular fracture and one iliac blade fracture). In addition there were two tibial plateau fractures, two tibial plafond fractures and one talar body fracture. Of note, the median age of horse riding patients was 39 years (*cf.* 25 yrs for all sports) and 85% of those affected were women. Motocross caused 24 fractures. Notably, there were three tibial diaphyseal fractures, three tibial plafond fractures, one avulsion fracture of the tibial spines and one lateral compression fracture of the pelvis.

The remaining 17.2% of sports-related fractures were caused by the activities listed in Table 3.10 (next page).

Sport	(n)	Age (yrs)	Gender (M:F, n)	Fractures (n)		
				Upper limb	Lower limb	Pelvis
Field hockey	19	25	10:9	17	2	0
Athletics	17	34	11:6	7	10	0
Boxing	15	24	13:2	15	0	0
Skateboarding	14	21	13:1	9	5	0
Trampolining	11	29	8:3	7	4	0
Sports climbing	10	34	7:3	5	4	1
Softball	7	-	4:3	6	1	0
Tennis	7	-	3:4	6	1	0
Netball	6	-	0:6	4	2	0
Cricket	5	-	5:0	4	1	0
Badminton	4	-	1:3	2	2	0
Roller-skating	4	-	1:3	4	0	0
Sledging	4	-	3:1	3	1	0
Arm wrestling	3	-	3:0	3	0	0
Gaelic football / hurling	3	-	3:0	3	0	0
Golf	3	-	2:1	0	3	0
Gymnastics	3	-	1:2	3	0	0
Ice hockey	3	-	3:0	3	0	0
Squash	3	-	2:1	3	0	0
Swimming	3	-	1:2	1	2	0
American football	2	-	2:0	1	1	0
Bowling	2	-	1:1	2	0	0
Frisbee	2	-	2:0	2	0	0
Go-karting	2	-	1:1	0	2	0
Kite surfing	2	-	1:1	2	0	0
Quad biking	2	-	2:0	2	0	0
Waterpolo	2	-	2:0	2	0	0
Weightlifting	2	-	2:0	2	0	0
Curling	1	-	0:1	1	0	0
Handball	1	-	1:0	1	0	0
Hang-gliding	1	-	1:0	1	0	0
Huskie racing	1	-	0:1	1	0	0
Lacrosse	1	-	1:0	1	0	0
Surfing	1	-	0:1	1	0	0
Volleyball	1	-	0:1	1	0	0
Windsurfing	1	-	1:0	0	1	0
Wrestling	1	-	1:0	1	0	0

Table 3.10 The number and frequency of fractures in Edinburgh adults resulting from the remaining 17.2% of sporting activities. The (median) age of affected patients is given for those sports involving injury to 10 or more patients. For each sport, the distribution of fractures across the appendicular skeleton and pelvis is also shown.

Direct blows / assaults / crush injuries

Fractures occurring as a result of intentional ('punching injuries') or unintentional direct blows, during altercations or assaults, or sustained by a crushing or compressive injury were included in this category. They accounted for 12.9% of all acute adult fractures, with 885 injuries occurring in 820 patients (1.08 per patient). For the purposes of data analysis these injuries were divided into 'intentional' and 'unintentional' direct blows.

The distribution curve for *intentional* direct blow fractures shown in Figure 3.5 is an example of a type B unimodal young male distribution proposed by Court-Brown and Caesar⁸⁸. There were 353 intentional direct blow fractures, and 324 (91.8%) occurred in men. These fractures accounted for 9.8% of all male fractures, and represented 14.8% of all fractures in 15 to 39 year old men. The majority of injuries (90.4%) affected the metacarpus, with the remainder affecting the finger phalanges (n=16), carpal bones (n=14), distal ulna (n=2), distal radius (n=1) and proximal ulna (n=1).

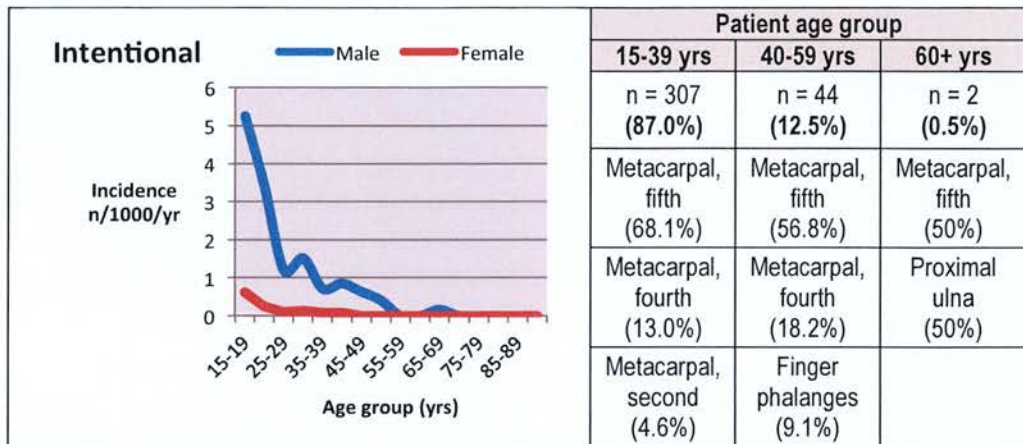


Figure 3.5 The age- and gender-related incidence of fractures occurring in Edinburgh adults and caused by intentional direct blows. The frequencies of the three most common fracture types, according to three broad patient age groups, are also shown.

Three patients suffered fractures of two metacarpals. Three hundred and thirteen patients sustained a single metacarpal fracture. Four patients sustained open fractures from a punching mechanism, referred to as a ‘fight bite’ injury¹¹⁸. As illustrated in Figure 3.6, the most commonly involved metacarpal was the fifth. The term ‘boxer’s fracture’ refers to a fracture of the fifth metacarpal neck. In this series of punching fractures involving the fifth metacarpal, the neck or head was involved on 33.1% of occasions, but the diaphysis was more commonly affected. However, when all fifth metacarpal head and neck fractures in men aged 15-39 yrs were analysed, 68.5% were due to a punching injury.

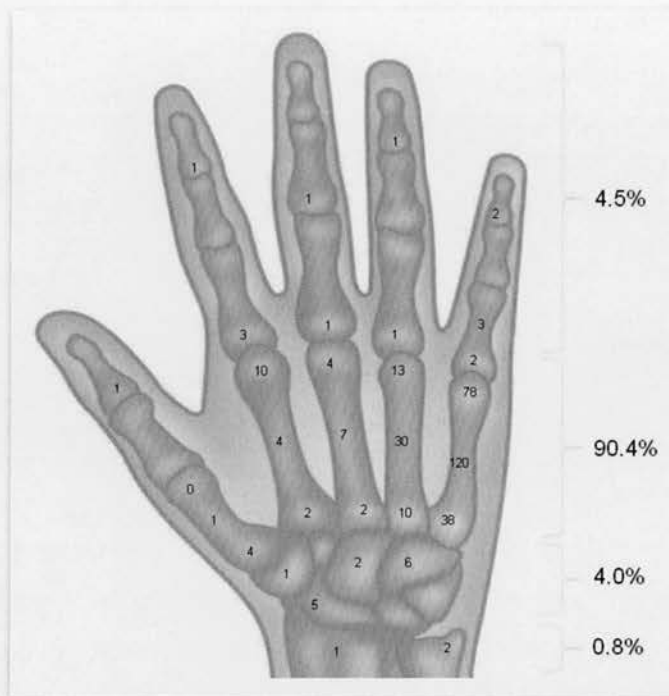


Figure 3.6 The anatomical distribution of fractures of the hand and wrist, caused by intentional direct blows, and occurring in Edinburgh adults. The proportion of phalangeal, metacarpal, carpal and distal forearm fractures is expressed as a percentage of the total. The number of basal / diaphyseal / distal injuries affecting the metacarpals and phalanges is also shown.

Unintentional direct blow fractures included any injury mechanism involving a direct blow to the skeleton, but not including blows caused by falling, sport or road traffic accidents. There were 533 of these fractures and the majority were caused by a blow (n=313) or a crush mechanism (n=183). Infrequently encountered mechanisms included bite injuries (n=4), one blunt missile injury (a 19 year old motor mechanic suffered a femoral diaphyseal fracture in a work-related accident) and fractures caused by forceful collision with a domestic pets (n=32).

The fracture distribution curve for *unintentional* direct blow fractures is shown in Figure 3.7, and represents a type C curve. The highest incidence occurred in young men, but was not as pronounced as with intentional direct blow fractures. In both sexes, the incidence was higher during the years of employment. Buhr and Cooke⁸⁴ described this as a type A or 'wage-earner's curve' in 1959. They noted that fractures falling into the wage-earner's category occurred predominantly in the hands and feet and proposed that many of these were sustained from injuries at work. An analysis of fracture type by patient age group in Figure 3.7 shows that this pattern of injury to the hands and feet has changed little in the past 50

years. In particular, the finger phalanges and metacarpals remain most at risk from accidental direct blow / crush injuries.

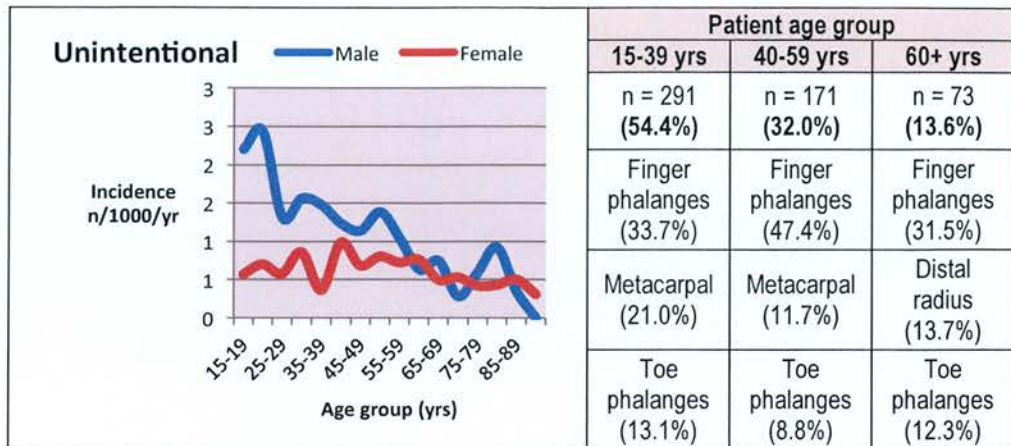


Figure 3.7 The age- and gender-related incidence of fractures occurring in Edinburgh adults, caused by unintentional direct blows (including crush, bite and missile injuries). The frequencies of the three most common fracture types, according to three broad patient age groups, are also shown.

There were 313 unintentional direct blow fractures, and 208 affected male patients (66.3%). The median age was 30 years (IQR, 21-44 yrs) for men and 40.5 years (IQR, 25-51 yrs) for women. The majority of these fractures were closed injuries (96.2%). Direct blows most commonly affected the finger phalanges (n=99, 31.4%), metacarpus (n=67, 21.3%) and toe phalanges (n=34, 10.8%). There were 183 crush fractures in 132 men (72.1%) and 51 women (27.9%), with median ages of 38 years (IQR, 26-49 yrs) and 43 years (IQR, 29.5-54 yrs) respectively. Half of all crush fractures affected the finger phalanges and 55.2% of these were open injuries (including two traumatic amputations). Toe phalanx fractures accounted for 15.2% of crush fractures with an open fracture rate of 28.6%. Metacarpus and metatarsus fractures each accounted for 8.7% (n=16) in this category and all were closed injuries. Crush injuries commonly affected the limb extremities and the highest overall open fracture rate (35.0%) was seen resulting from this mechanism.

Collisions with a popular domestic pet caused 32 fractures, sustained primarily by older female patients (84.4%), with a median age of 59 years (IQR, 52-64 yrs). Injury to the lower limb was more common than that of the upper limb (56% vs. 44%). Direct blows from dogs caused five fractures of the ankle, four of the tibial plateau, three tibial diaphyseal fractures, two hip fractures and a distal femoral fracture. Upper limb fractures included five of the distal radius, three of the proximal humerus and two of the proximal radius.

Road traffic accidents

Road traffic accidents accounted for 361 acute fractures (5.3% of the total), occurring in 277 patients (1.30 per patient). Four-fifths of fractures occurred in men. In common with most other modes of injury, fractures of the upper limb predominated (60.7%). However, RTAs accounted for the second highest frequency of fracture of the pelvis (3.6%), after falls from a height (9.2%). The frequency of multiple fractures varied between different groups. In patients who had suffered a fracture of the pelvis as the index fracture, 61.1% had suffered multiple fractures. In patients whose index fracture affected the lower limb, 39.8% sustained other fractures. In those with an upper limb fracture, multiple fractures were present in only 15.1%. The difference identified between the first two groups and upper limb group was highly statistically significant ($p < 0.0001$, chi-square test). The overall fracture distribution curve for RTA fractures is shown in Figure 3.8. The pattern resembles a type B unimodal young male distribution, but the obvious difference is the second peak in older male age groups. The incidence in women remains low throughout adult life. The rate of open fractures was 8.7%.

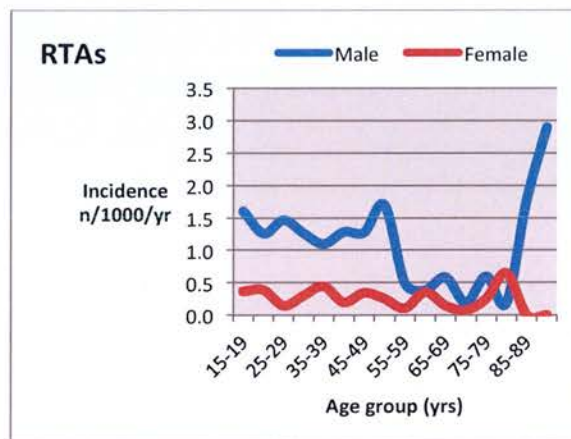


Figure 3.8 The age- and gender-related incidence of fractures occurring in Edinburgh adults, caused by road traffic accidents (RTAs).

Patient Group	Fractures (n, %)	Patients (n, %)	Median age (yrs, IQR)	Gender ratio (M:F, %)	'n' per patient
Pedal cyclist	123 (34.1)	113 (40.8)	39 (27-49)	68:32	1.11
Motorcyclist	117 (32.4)	80 (28.9)	34 (24-44)	95:5	1.46
Pedestrian	78 (21.6)	53 (19.1)	32.5 (21-60.5)	80:20	1.45
Vehicle occupant	43 (11.9)	31 (11.2)	37 (29-54)	58:42	1.36
All	361 (100)	277 (100)	36 (25-49)	77:23	1.30

Table 3.11 The number and frequency of fractures sustained by Edinburgh patients involved in road traffic accidents. The number, age distribution and gender ratio of patients affected is also shown.

The majority of patients suffering fractures in RTAs were pedal cyclists involved in a collision with another vehicle or pedestrian (Table 3.11, previous page). Multiple fractures were uncommon in this group, as were open fractures (Table 3.12). Fractures sustained by pedal cyclists commonly affected the upper limb (28 proximal radius, 17 clavicle and 15 distal radius fractures), presumably sustained when falling from the bicycle. In addition, there was one cycling-related lateral compression fracture of the pelvis identified.

Patient Group	(n)	Upper limb (%)	Lower limb (%)	Pelvis (%)	% Open fractures
Pedal cyclist	123	84.6	14.6	0.8	2.4
Motorcyclist	117	53.0	43.6	3.4	14.5
Pedestrian	78	43.6	51.3	5.1	11.5
Vehicle occupant	43	39.5	51.2	9.3	7.0
All	361	60.7	35.7	3.6	8.9

Table 3.12 The distribution of fractures across the appendicular skeleton and pelvis, identified in Edinburgh patients involved in road traffic accidents. The frequency of open fractures is also shown.

Eighty motorcyclists sustained 117 fractures. Injured motorcyclists represented a young male adult age group, with the oldest affected motorcyclist being 44 years of age. The highest number of multiple fractures (1.46 fractures per patient) was identified in this group, and 95.3% of those injured were men. The commonest fracture types seen were those of the metacarpus (n=14), ankle (n=10) and clavicle (n=10) but a significant number of fractures affected the tibia (n=14) and femur (n=9) in this young adult population. The highest open fracture rate was noted in motorcyclists (14.5%). Of the 17 open fractures sustained by motorcyclists, 11 (64.7%) were classified as grade 3 according to Gustilo and Anderson¹¹², and 14 (82.3%) involved the lower limb or pelvis.

Fifty three pedestrians suffered 78 fractures. Men were affected more often than women and injury to the lower limb was most common. The commonest fractures encountered were those of the tibial diaphysis (n=9), distal radius (n=9) and tibial plateau (n=7). The open fracture rate was 11.3% and all but one of these injuries involved the lower limb (88.9%). The frequency of grade 3 open fractures was 77.8% with five seen in the tibia and two in the femur. Four fractures of the pelvis were noted, affecting a much older age group (mean age 70.8 yrs), with one involving the acetabulum and three the pelvic ring.

Forty three fractures were sustained by 31 vehicle occupants. Twenty drivers with a median age of 42 years (IQR, 29-56.5 yrs) suffered 28 fractures (1.40 per patient). Thirteen

passengers aged 33 years (IQR, 27-45 yrs) sustained 17 fractures (1.31 per patient). The upper and lower limbs were affected equally and common fractures seen involved the tibial plateau (n=6), clavicle (n=5) and femoral diaphysis (n=4). The rate of open fractures (6.7%) was lower than that of pedestrians and motorcyclists. Three pelvic fractures were recorded. One driver sustained a posterior wall acetabular fracture in association with a posterior dislocation of the femoral head.

Falls down stairs

Fractures sustained as a result of falling down three or more stairs accounted for 3.8% of injuries recorded. Two hundred and thirty two patients sustained 260 fractures (1.12 per patient), and women were affected approximately twice as often as men. There was a trend towards an increased frequency of multiple fractures in patients aged 60 years or older (1.18 vs. 1.07 per patient; $p=0.06$, chi-square test). The fracture distribution curve is shown in Figure 3.9.

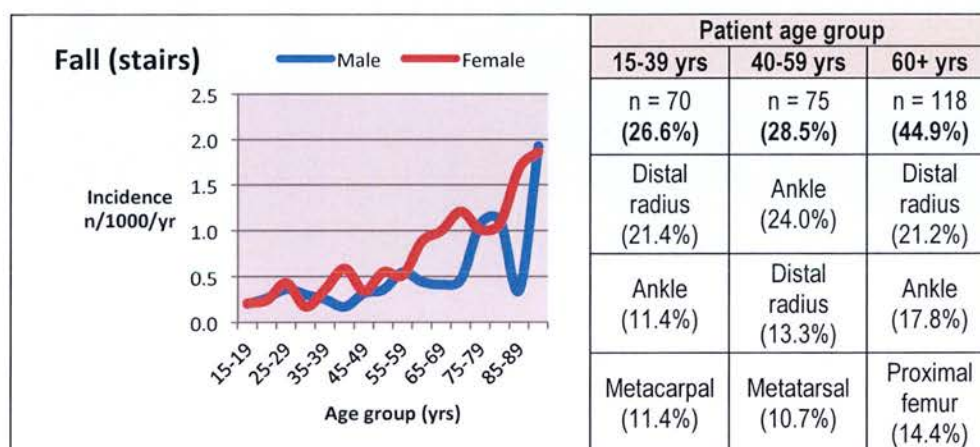


Figure 3.9 The age- and gender-related incidence of fractures occurring in Edinburgh adults, caused by falls down three or more stairs. The frequencies of the three most common fracture types, according to three broad patient age groups, are also shown.

Similarities can be drawn between the distribution of these fractures and simple fall fractures. They are both examples of Buhr and Cooke's J-shaped curve⁸⁴, or Court-Brown and Caesar's type F unimodal older male and female distribution curve⁸⁸. Patients with fractures from falling down stairs were on average slightly younger than those suffering a simple fall fracture. The most common fractures sustained were those of the distal radius (n=50) and ankle (n=47). There were three fractures of the femoral diaphysis and 19 proximal femoral fractures, occurring exclusively in adults aged 55 years or older. The same

was noted for the four pelvic fractures identified, as these were all sustained by patients aged at least 60 years.

Falls from a height

All falls from approximately six feet (1.8 m) or greater constituted ‘falls from a height’ and 249 fractures (3.6% of all fractures) in 198 patients resulted from this mode of injury. The overall fracture rate was 1.26 per patient. One hundred and fifty four men sustained 193 fractures (1.25 per patient), and 44 women sustained 56 fractures (1.27 per patient). The age-related distribution of male and female patients did not differ significantly. Figure 3.10 shows that fractures resulting from falls from a height follow a type B distribution, predominantly affecting young men. A number of these injuries occur in male ‘wage-earners’ (Buhr and Cooke type A⁸⁴) suggesting an association with employment in some instances.

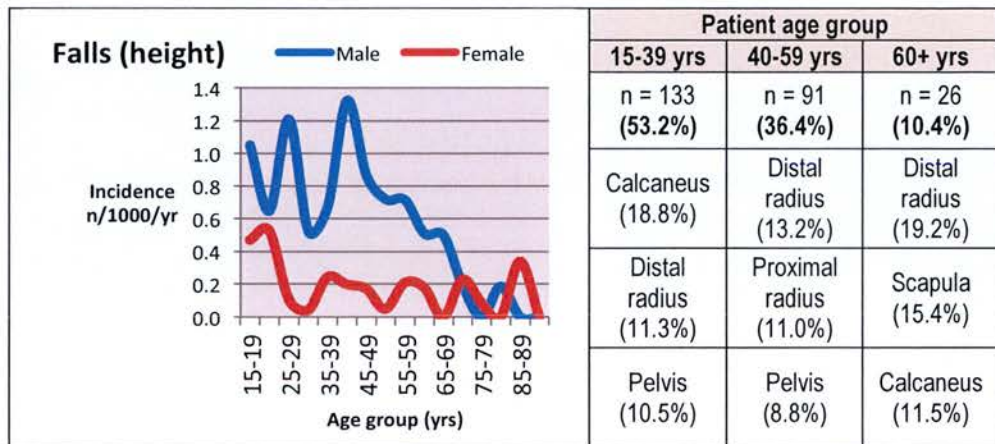


Figure 3.10 The age- and gender-related incidence of fractures occurring in Edinburgh adults, caused by falls from a height of six feet or greater. The frequencies of the three most common fracture types, according to three broad patient age groups, are also shown.

Falls from a height were associated with the highest frequency of fractures to the pelvis (9.2%) when compared to all other modes of injury. The frequency of lower limb fractures (50.2%) was also higher than most other injury modes. The frequency of multiple fractures varied between different groups. In patients with a fracture of the pelvis, 70.0% had suffered multiple fractures. In patients with lower limb fractures, 21.9% sustained other fractures. In upper limb fracture patients, the frequency was even less at 18.5% and the difference between groups was highly statistically significant (p<0.0001, chi-square test).

Nil / spontaneous

Thirty nine fractures (0.6%) occurred in 39 patients under conditions whereby the skeleton was subjected to apparently normal physiological loading. These injuries represented insufficiency fractures through bone pathologically weakened by bone tumour (benign disease or malignancy). Half of all affected patients were aged between 60 years and 80 years of age and 77% were women. Three-quarters of fractures affected the lower limb and the remainder occurred in the upper limb. Figure 3.11 demonstrates the predominance of these injuries for older female patients.

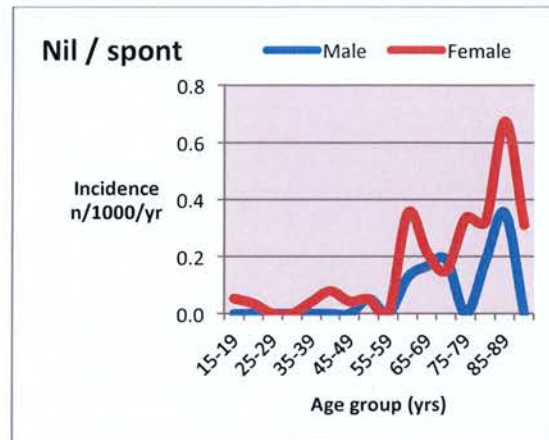


Figure 3.11 The age- and gender-related incidence of pathological fractures occurring in Edinburgh adults, sustained under physiological loads, and secondary to malignant disease.

Twenty three (79.3%) of the 29 lower limb fractures affected the femur, and the majority of these were proximally situated. There were two distal tibial fractures and four fractures of the metatarsus. There were ten fractures of the upper limb, and the humerus was affected five times (50%). The remaining five fractures occurred in the distal radius (n=2) and finger phalanges (n=3).

3.4 Fractures of the shoulder girdle

Fractures of the shoulder girdle included those of the scapula, clavicle and proximal humerus. A total of 835 shoulder girdle fractures were sustained by 827 patients with a slight female preponderance (54.7%). Fifty scapula fractures were sustained by 48 patients with two patients suffering bilateral injuries. In total, 279 patients sustained 280 clavicle fractures including one patient who suffered a recurrent fracture of the same clavicle. A total of 505 proximal humerus fractures were suffered by 500 patients; three patients sustained bilateral fractures and two suffered fracture recurrence. The distribution of shoulder girdle fractures and associated fractures are presented in Tables 3.13 and 3.14.

	Prox. Humerus	Clavicle	Scapula	p-value
Fractures (n, %)	505 (60.5)	280 (33.5)	50 (6.0)	-
Gender ratio (M:F, %)	31:69	71:29	46:54	p<0.001*
Incidence (n/10,000/yr)	9.3 (8.5-10.1)	5.1 (4.5-5.8)	0.9 (0.7-1.3)	-
Males	6.1 (5.1-7.1)	7.7 (6.7-8.9)	0.9 (0.6-1.3)	
Females	12.2 (10.9-13.5)	2.8 (2.2-3.5)	0.9 (0.6-1.4)	
Median age (yrs, IQR)	69.5 (55-80)	36.5 (22-59)	51 (34-74)	p<0.001 ^k
Men	60 (42-74)	31 (21-51)	34 (25-49)	p<0.001 ^k
Women	73 (61-82)	61 (34-80)	68 (50-79)	p<0.001 ^k
Mode of injury (n, %)				
Simple fall	389 (77.5)	94 (33.6)	21 (41.2)	
Sports-related	21 (4.2)	98 (35.0)	6 (11.8)	
Direct blow	12 (2.4)	9 (3.2)	1 (2.0)	
Other	29 (5.8)	21 (7.5)	3 (5.9)	
RTA	24 (4.8)	37 (13.2)	6 (11.8)	
Fall down stairs	16 (3.2)	12 (4.3)	7 (13.7)	
Fall from a height	10 (2.0)	9 (3.2)	7 (13.7)	
Nil	1 (0.2)	0	0	
Open injuries (n, %)	0	0	0	-

Table 3.13 The number and incidence (with 95% CI) of fractures of the shoulder girdle sustained by Edinburgh adults. The age distribution and gender ratio of affected patients is shown. The distribution of injury modes responsible is also given. *Chi square test. ^kKW test. (RTA = road traffic accident).

Age group (yrs)	Scapula		Clavicle		Prox. Humerus	
	15-54	55+	15-54	55+	15-54	55+
Ipsilateral upper limb	6	6	7	4	6	13
Contralateral upper limb	1	2	2	0	2	6
Lower limb (hip #)	0	1	0	1	0	17
(non-hip #)	1	0	4	0	4	9
Pelvis	1	1	0	1	1	4
Total	9	10	13	6	13	49
% with associated #s	27.6	47.4	4.1	5.8	11.1	11.9

Table 3.14 The distribution of associated fractures for each shoulder girdle fracture type, occurring in Edinburgh adults aged 15 to 54 years, and 55 years or more.

Scapula

The scapula is an integral part of the osseous connection between the upper limb and axial skeleton. It serves as a point of attachment for various muscles, ligaments and tendons and articulates with the proximal humerus at the glenoid fossa to form the glenohumeral joint. Historically, scapular fractures have occurred predominantly as the result of high energy trauma¹¹⁹⁻¹²¹ with a significant frequency of associated injuries (including pneumothorax, pulmonary contusion, rib fracture, head injury and blunt abdominal trauma)¹²². A report of forty cases from Texas in the 1960's showed scapular body fractures to be most common (75%), followed by scapular neck fractures (20%) and glenoid fossa fractures (15%)¹²¹. In a recent summary of the literature, van Noort noted fractures of the body and spine to be most common (~50%), followed by the neck (~25%), glenoid fossa (~10%), acromion (~8%) and coracoid (~7%) processes¹²³. An analysis of ten years of scapular fractures in Sweden found glenoid fossa fractures to be most common (30%), with two-thirds resulting from glenohumeral dislocations²⁵.

Subtype	(n)	(%)	Gender ratio (M:F, %)	Median age (yrs, IQR)	% RTA / Height	% with associated #s
Acromion	6	12	83:17	50 (37-73)	28.6	33.3
Body	14	28	50:50	45 (35-77)	57.1	64.3
Coracoid	1	2	0:100	75	0	0
Glenoid:	22	44	36:64	51.5 (40-69)	9.1	27.3
Anterior rim	9					
Posterior rim	3					
Inferior rim	9					
Multifragmentary	1					
Neck	7	14	43:57	46 (33-73)	14.3	28.6
All	50	100	46:54	51 (35-74)	26.0	40.0

Table 3.15 The number and frequency of scapula fracture subtypes. The age distribution and gender ratio of affected patients is given. The proportion of fractures occurring from high energy mechanisms, and those associated with multiple fractures are shown. (*RTA* = road traffic accident; *Height* = fall from a height).

The results of this study on Edinburgh adults reveal the frequency of glenoid fossa fractures is higher than that of the body and spine (Table 3.15, above). Ninety percent of glenoid fractures resulted from low energy trauma. In keeping with the findings of Ideberg *et al*²⁵, 68.2% occurred in conjunction with a glenohumeral dislocation and two-thirds of those affected were women. The overall fracture distribution curve (Fig. 3.12) reflects this pattern of injury.

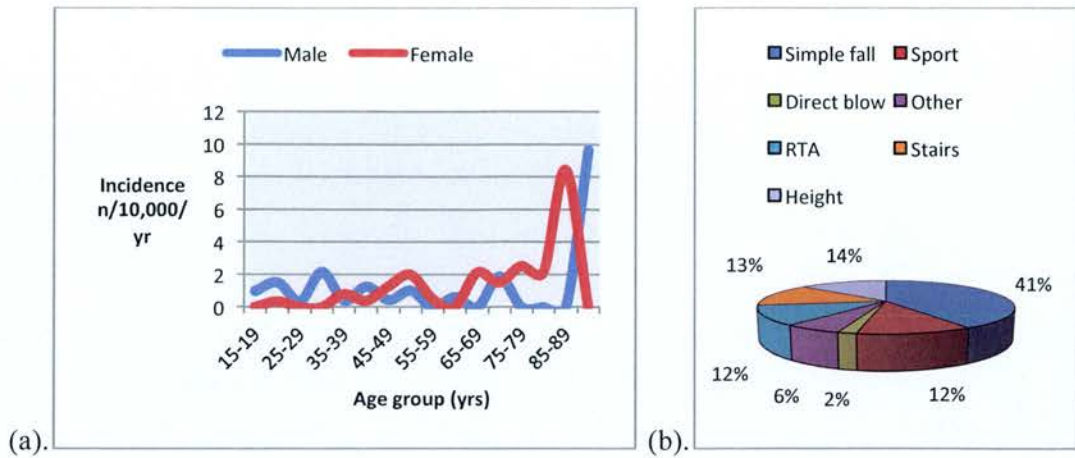


Figure 3.12 (a) The age- and gender-related incidence of scapular fractures occurring in Edinburgh adults. (b) The frequencies of the injury modes involved.

However, there remains a significant proportion of high energy injuries sustained by younger adults. The distribution curve shows a slightly higher incidence in young men than in young women. Overall, affected male patients were half the age of affected women (34 yrs vs. 68 yrs) and a significant number sustained fractures from falls from a height or RTAs. In particular, scapular body fractures were more often the result of high energy trauma. Two-thirds of these patients also suffered associated fractures elsewhere. The proportion of scapula fractures in this series that occurred as part of a multiple fracture episode was 40%. Given that the literature suggests 61% to 98% of scapula fractures are associated with concomitant injuries (including many injury types not formally recorded for this study), the figure of 40% is likely to be consistent with previous reports¹²³. A 31 year old man suffered concomitant fracture of the scapular neck and ipsilateral clavicle from a football injury. This ‘floating shoulder’ injury is known to be a rare occurrence¹²⁴, (the calculated incidence from this study was 0.02/10,000/yr). The incidence of scapula fractures was found to be the same for men and women. While many of the injuries suffered by female patients were sustained by low energy trauma, a number of those affecting men occurred as a result of high energy violence.

Clavicle

Clavicle fractures are common injuries in young active populations, especially those who participate in activities or sports where high speed falls (motorcycling, mountain biking) or collisions (football, rugby) are frequent¹²⁵. The literature suggests clavicle fractures account for 35% of shoulder injuries^{126, 127}. The Allman classification broadly groups clavicle fractures by their location in the proximal, middle or distal one-third of the bone¹²⁸.

Recognising that distal one-third fractures were associated with higher rates of delayed and non-union, Neer²⁹ divided them into three subgroups (subsequently modified by Rockwood¹²⁹) based on their displacement and the integrity of ligamentous attachments. In 1998, Robinson reported on 1,000 consecutive clavicle fractures in the Edinburgh population and devised a classification system based upon prognostic variables (intra-articular fracture extension, comminution and displacement)²⁸. Figure 3.13 (next page) illustrates this system. Robinson reported substantial interobserver reliability and intraobserver reproducibility (average kappa coefficients of 0.77 and 0.84, respectively) for his classification system.

The majority of fractures occur in the mid-shaft of the clavicle, affecting predominantly young adult groups. Fractures of the distal part tend to affect older adults¹³⁰. Fractures of the medial clavicle are least common, accounting for between 2% and 9.3% of clavicle fractures¹³¹. Robinson's analysis of fractures in Edinburgh adults between 1988 and 1994 showed that fractures of the middle three-fifths predominated (69%), followed by those of the lateral one-fifth (28%) and medial one-fifth (3%)²⁸. Two hundred and eighty clavicle fractures occurred in 279 patients. The distribution of fractures from the present series is shown below (Table 3.16).

Fracture subtypes	Number (%)	Patient age (yrs, range)	Men	Women	Gender ratio (M:F, %)	% from RTA / Height
1A1	3	53.0 (15-91)	1	2	33:67	0
1A2	1	15	1	0	100:0	0
1B1	4	45.0 (18-63)	3	1	75:25	25.0
1B2	0	-	-	-	-	0
All type 1	8 (2.9)	44.3 (15-91)	5	3	63:37	12.5
2A1	16	37.2 (19-81)	13	3	81:19	25.0
2A2	41	33.7 (15-93)	34	7	83:17	17.1
2B1	106	53.7 (15-92)	76	30	72:28	18.9
2B2	8	33.5 (18-48)	6	2	75:25	37.5
All type 2	171 (61.1)	37.0 (15-93)	129	42	75:25	19.9
3A1	56	54.5 (18-92)	32	24	57:43	12.5
3A2	5	40.6 (15-59)	3	2	60:40	20.0
3B1	32	45.4 (15-91)	27	5	84:16	6.3
3B2	8	62.8 (40-84)	4	4	50:50	12.5
All type 3	101 (36.0)	51.6 (15-92)	66	35	65:35	10.9
Total	280 (100)	42.5 (15-93)	200	80	71:29	16.4

Table 3.16 The number and frequency of clavicle fractures by subtype, according to the Robinson classification²⁸. The age- (mean and range) and gender-related distribution of affected patients is shown. The proportion of fractures sustained by high energy injury provided. (*RTA* = road traffic accident; *Height* = fall from a height).

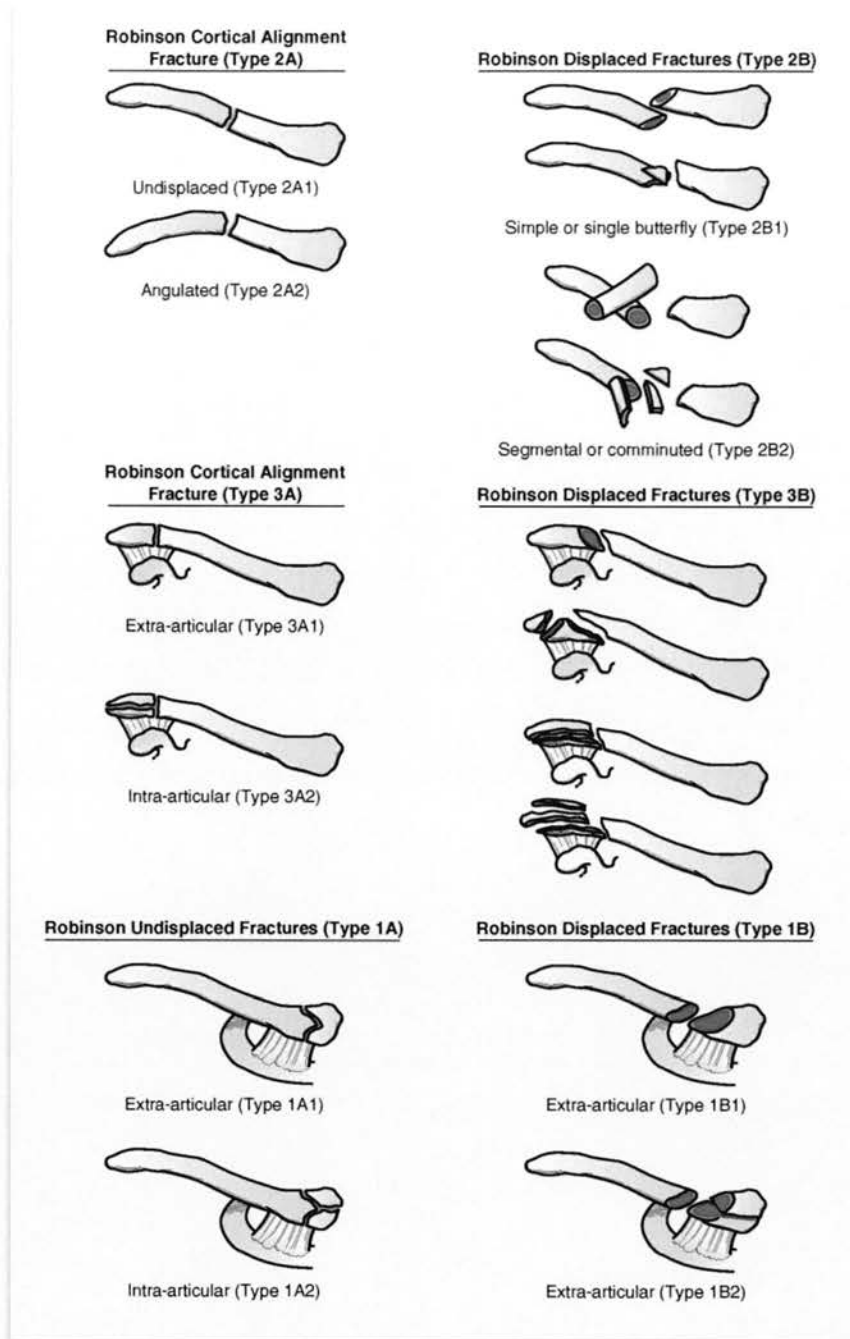


Figure 3.13 The Robinson classification system for fractures of the clavicle²⁸. Type 1 fractures involve the medial one-fifth, type 2 the middle three-fifths, type 3 the lateral one-fifth. Type A fractures are undisplaced and type B fractures are displaced. (Reproduced with permission from Lippincott Williams & Wilkins publishers).

Male patients accounted for 71.4% of those involved. The median age of men was half that of affected women (31 yrs vs. 61 yrs). Clavicle fractures represented 4.1% of all fractures and 33.5% of shoulder girdle fractures. The frequency of associated fractures was low (4.1% in adults aged less than 55 yrs, 5.8% in those 55 yrs and older). Fractures of the middle

three-fifths were most common, followed by those of the lateral one-fifth and medial one-fifth. The overall fracture distribution curve shown in Figure 3.14 is an example of a type G curve (bimodal male, unimodal older female distribution) as described by Court-Brown and Caesar⁸⁸.

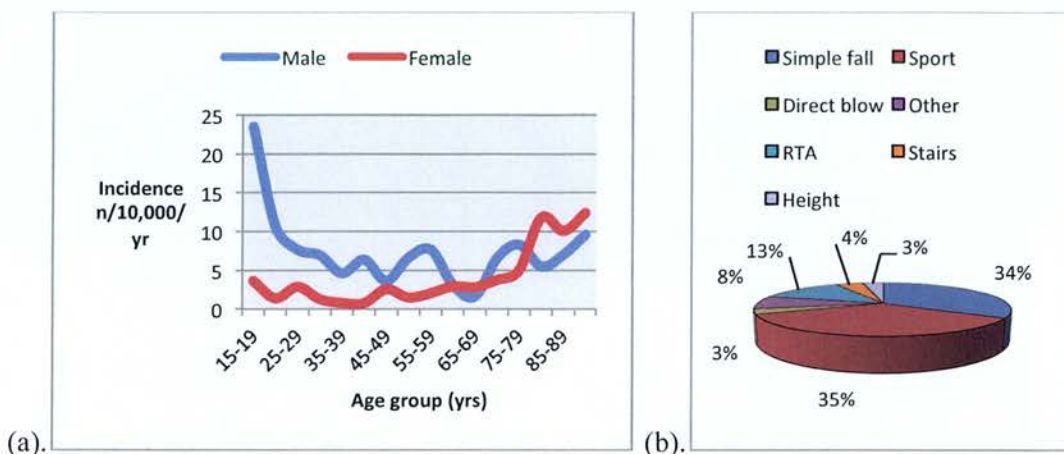


Figure 3.14 (a) The age- and gender-related incidence of clavicle fractures occurring in Edinburgh adults. (b) The frequencies of the injury modes involved. (RTA = road traffic accident; Stairs = fall down stairs; Height = fall from a height).

Fracture subtypes	Simple fall	Sports-related	Direct blow	Other	RTA	Fall (stairs)	Fall (height)
1A1	2	1	0	0	0	0	0
1A2	0	1	0	0	0	0	0
1B1	1	1	0	0	1	1	0
1B2	0	0	0	0	0	0	0
All type 1	3 (3.2)	3 (3.1)	0 (0)	0 (0)	1 (2.7)	1 (8.3)	0 (0)
2A1	3	6	1	1	3	1	1
2A2	8	24	0	2	5	0	2
2B1	28	42	5	7	18	4	2
2B2	0	4	1	0	2	0	1
All type 2	39 (41.5)	76 (77.6)	7 (77.8)	10 (47.6)	28 (75.7)	5 (41.7)	6 (66.7)
3A1	32	9	1	4	4	3	3
3A2	2	0	0	2	1	0	0
3B1	14	8	1	5	2	2	0
3B2	4	2	0	0	1	1	0
All type 3	52 (55.3)	19 (19.3)	2 (22.2)	11 (52.4)	8 (21.6)	6 (50.0)	3 (33.3)
Total	94 (100)	98 (100)	9 (100)	21 (100)	37 (100)	12 (100)	9 (100)

Table 3.17 The modes of injury responsible for each clavicle fracture subtype, according to the Robinson classification system²⁸.

Fractures of the medial one-fifth were uncommon (2.9%). Fractures of the lateral one-fifth occurred in older patients, and the majority were sustained by low energy trauma (Table 3.17, above). Indeed, lateral one-fifth fractures accounted for half of all clavicle fractures

sustained by falling down stairs or falling from a standing height. The relative frequency of these fractures has increased in the Edinburgh population over the last 13 years (36% vs. 28%).

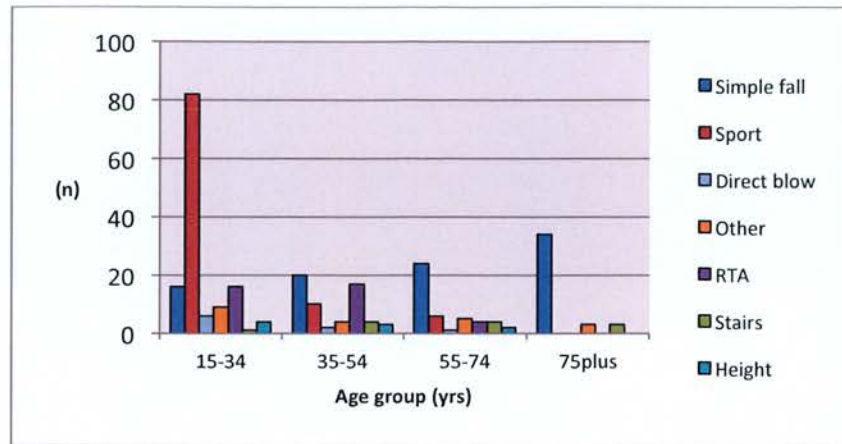


Figure 3.15 The distribution of injury modes causing a clavicle fracture in Edinburgh adults, and arranged according to patient age group. (RTA = road traffic accident; Stairs = fall down stairs; Height = fall from a height).

Fractures of the middle three-fifths of the clavicle were sustained by the youngest patient group and 20% of these injuries resulted from relatively high energy trauma (RTAs or falls from a height). Middle three-fifths injuries accounted for three-quarters of sports-related clavicle fractures. When analysing all fracture subtypes, those sustained by patients with a young average age were more often associated with high energy injury. Figure 3.15 illustrates this trend. The number of fractures from RTAs, falls from a height, or sport decreased with advancing age.

Proximal humerus

Fractures of the proximal humerus are one of the most common fractures seen in the elderly. The incidence is generally low in adults aged less than 40 years and increases exponentially thereafter¹³². The literature suggests the frequency of these fractures in older adults is increasing. A recent Finnish study has shown that the incidence in elderly Finns has trebled from 3.2/10,000/yr in 1970 to 10.5/10,000/yr in 2002¹³³. In Japan, although the incidence is lower, it is also increasing. In Japanese adults (aged 35 yrs and older) the incidence of proximal humeral fractures increased over a ten-year period from 1.0 to 1.7 (n/10,000/yr) in men, and 4.2 to 4.8 (n/10,000/yr) in women¹³⁴.

Neer's four-part classification system of proximal humeral fractures is still commonly used by virtue of its simplicity³¹. The AO / OTA system¹⁴ uses an alphanumeric triad to describe the various fracture subtypes (see Table 3.20, next page, and the Appendix). Due to the difficulty in appreciating fracture lines and displacement on plain radiographs, many studies have shown that interobserver reliability and intraobserver reproducibility are only moderate for both classification systems^{135, 136}. The addition of CT imaging can improve reliability¹³⁵. Notably, this series of proximal humeral fractures was classified using plain radiographs.

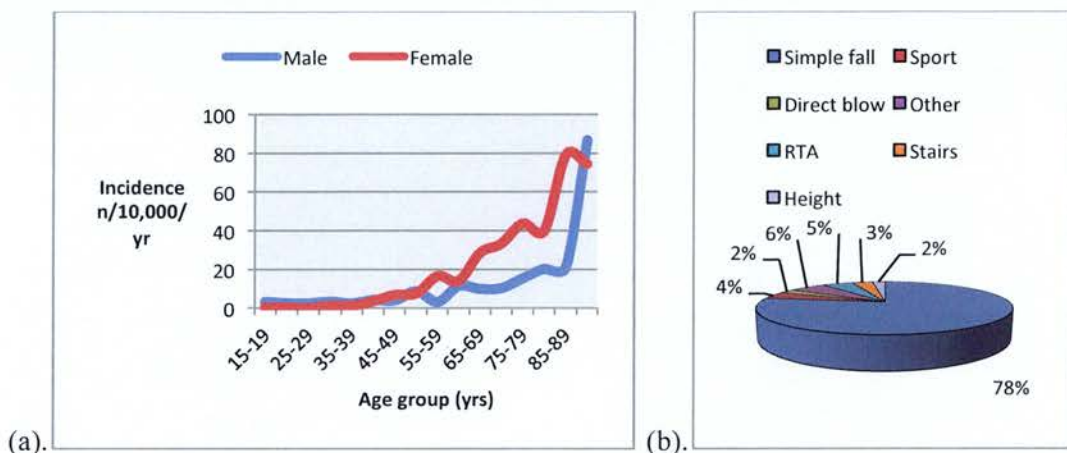


Figure 3.16 (a) The age- and gender-related incidence of proximal humeral fractures occurring in Edinburgh adults. (b) The frequencies of the injury modes involved. (RTA = road traffic accident; Stairs = fall down stairs; Height = fall from a height).

The 505 proximal humeral fractures represented 60.5% of shoulder girdle fractures, and 7.3% of all fractures (Table 3.15). Women accounted for 69.2% of those injured. The incidence was 9.3/10,000/yr and this represents an increase from 6.9/10,000/yr in Edinburgh adults from 1992 to 1996¹³⁷. The incidence in women was double that of male patients (12.2 vs. 6.1/10,000/yr). In patients aged 55 years or more, 11.9% presented with associated fractures (Table 3.16). Half of these affected the lower limb and 17 were proximal femoral fractures.

The fracture distribution curve (Fig. 3.16) shows a type F unimodal older male and female pattern. The incidence in women doubled every decade from the age of 40 years, from 3.6/10,000/yr in those aged 40 to 44 years, peaking at 79.2/10,000/yr in elderly women. The incidence in men was slightly higher than that in women until the age of 55 to 59 years. A steep increase in incidence was also seen in men, but not until the age of 70 years.

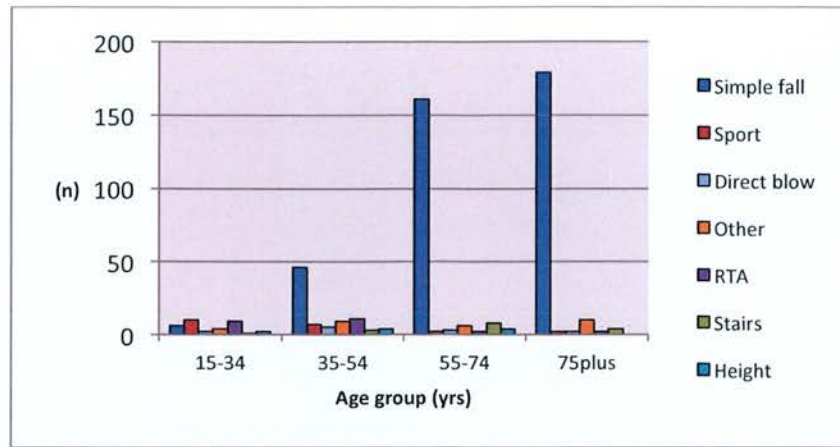


Figure 3.17 The distribution of injury modes causing fractures of the proximal humerus in Edinburgh adults, and arranged according to patient age group. (RTA = road traffic accident; Stairs = fall down stairs; Height = fall from a height).

In patients aged 15 to 34 years the commonest injury modes were sports-related injuries, RTAs and simple falls from a standing height. Eleven of 34 (32.3%) fractures in this age group were associated with glenohumeral dislocation. In all groups aged more than 35 years of age, simple falls were responsible for the vast majority of injuries.

Type	Group
Extra-articular, unifocal fractures (11-A)	Greater tuberosity (11-A1)
	Surgical neck, metaphysis impacted (11-A2)
	Surgical neck, metaphysis non-impacted (11-A3)
Extra-articular, bifocal fractures (11-B)	Three-part surgical neck fracture, metaphysis impacted (11-B1)
	Three-part surgical neck fracture, metaphysis non-impacted (11-B2)
	Extra-articular fracture with glenohumeral dislocation (11-B3)
Articular fractures (11-C)	Slight displacement (11-C1)
	Marked displacement (11-C2)
	With glenohumeral dislocation or head splitting fracture (11-C3)

Table 3.18 A description of the types and groups of fractures of the proximal humerus according to the AO classification system.

Table 3.18, above, outlines the AO classification system for proximal humeral fractures and the relevant illustrations can be found at the Appendix. Table 3.19 (next page) shows the distribution of proximal humeral fractures in the present series, according to this system. Two-thirds of fractures were AO type A unifocal injuries and the commonest subtypes involved fractures of the greater tuberosity or surgical neck. Type B bifocal fractures accounted for one-fifth, and the majority of these were impacted fractures of the surgical neck with an associated tuberosity fracture. Type C articular fractures were seen in 16.2%.

In contrast to many type C fractures in other anatomical regions, there was a higher involvement of female patients than in type A and B fracture subgroups.

Fracture groups	Number (%)	Mean age (yrs, range)	Men	Women	Gender ratio (M:F, %)	% from RTA / Height
A1	106	57.2 (22-94)	40	66	38:62	8.5
A2	158	70.1 (15-99)	45	113	28:72	3.8
A3	53	69.0 (16-92)	23	30	43:57	9.4
All type A	317 (64.8)	65.6 (15-99)	108	209	34:66	6.3
B1	82	69.9 (29-100)	20	62	24:76	8.5
B2	10	69.0 (32-90)	5	5	50:50	10.0
B3	2	47.0 (34-60)	1	1	50:50	0
All type B	94 (19.0)	69.3 (29-100)	26	68	28:72	8.5
C1	35	70.3 (42-89)	8	27	23:77	8.6
C2	18	71.8 (40-101)	2	16	11:89	5.6
C3	27	61.4 (27-86)	9	18	33:67	3.7
All type C	80 (16.2)	67.6 (27-101)	19	61	24:76	6.3
Total	491 (100)	66.8 (15-101)	153	341	31:69	6.7

Table 3.19 The number and frequency of proximal humeral fractures in Edinburgh adults, arranged according to the AO classification system. The age- and gender-related distribution of affected patients is shown. The proportion of fractures resulting from high energy trauma is given. Notably, eleven fractures were not classified due to unavailable radiographs.

3.5 Humeral shaft fractures

Estimates suggest that humeral shaft fractures account for between one percent and five percent of all fractures, depending on the population studied^{93, 138, 139}. In 1975, Mast *et al* reported on 240 humeral shaft fractures treated at a level one trauma centre in the United States¹⁴⁰. They found that 60% occurred in patients aged 35 years or less and 28% were open injuries. In contrast, the majority of more recent studies suggest a very different pattern of injury. A study performed in Edinburgh between 1989 and 1992 found a distinct bimodal age distribution with peaks in the third and seventh decades of life¹³⁹. Less than 10% of these fractures were open injuries. A similar bimodal distribution was seen in a study of Asian adults performed in Taiwan¹⁴¹. Ekholm and colleagues examined humeral shaft fractures in Swedish citizens from 1998 to 1999¹³⁸. They too described a bimodal distribution and reported 75% of fractures occurring in patients aged 50 years or more.

Fracture groups	Edinburgh 1989 to 1992 frequency (%)	Stockholm 1998 to 1999 frequency (%)
A1	29.2	37.7
A2	10.8	8.6
A3	23.3	14.7
All type A	63.3	61.0
B1	17.1	23.8
B2	8.3	4.5
B3	0.8	1.3
All type B	26.2	29.6
C1	5.4	7.2
C2	3.3	1.4
C3	1.7	0.8
All type C	10.4	9.4

Table 3.20 The reported frequencies of humeral shaft fracture types and groups, classified according to the AO system, in the adult populations of Edinburgh (1989 to 1992)¹³⁹ and Stockholm (1998 to 1999)¹³⁸.

Humeral shaft fractures are best classified using the alphanumeric system of the AO Foundation¹³, since adopted by the OTA¹⁴. Simple fracture types (type A) are further divided into simple spiral (A1), simple oblique (A2) and simple transverse (A3) groups. Fractures with a wedge fragment (type B) are termed spiral wedge (B1), bending wedge (B2) and fragmented wedge (B3). Complex fractures (type C) involve comminution or segmentation and may be spiral complex (C1), segmental (C2) or irregular (C3) with extensive comminution. Table 3.20, above, shows the frequency of each AO fracture type in two defined adult populations.

The present series of fractures affecting Edinburgh adults contained 69 humeral shaft fractures sustained by 33 (47.8%) men and 36 (52.2%) women. Male patients represented a younger group with a median age of 46 years (IQR, 30-62 yrs), while women had a median age of 74.5 years (IQR, 56-85 yrs). The overall median age was 60 years, five years older than previously reported in Edinburgh¹³⁹. Humeral shaft fractures accounted for 1.0% of all fractures and 1.7% of upper limb fractures. The incidence was 1.3/10,000/yr, which is consistent with published data⁹³, and was equal in both men and women. The resultant distribution curve (Fig. 3.18) is a type F, with peak fracture incidence seen in older patient groups. Of note, there was a low background incidence in young men. A familiar bimodal distribution was seen when analysing fracture *number* by patient age group and gender; the same curve produced from the Edinburgh population 17 years previously¹³⁹. Adults aged 40 years or less tended to be male, while those in older age groups were more often female.

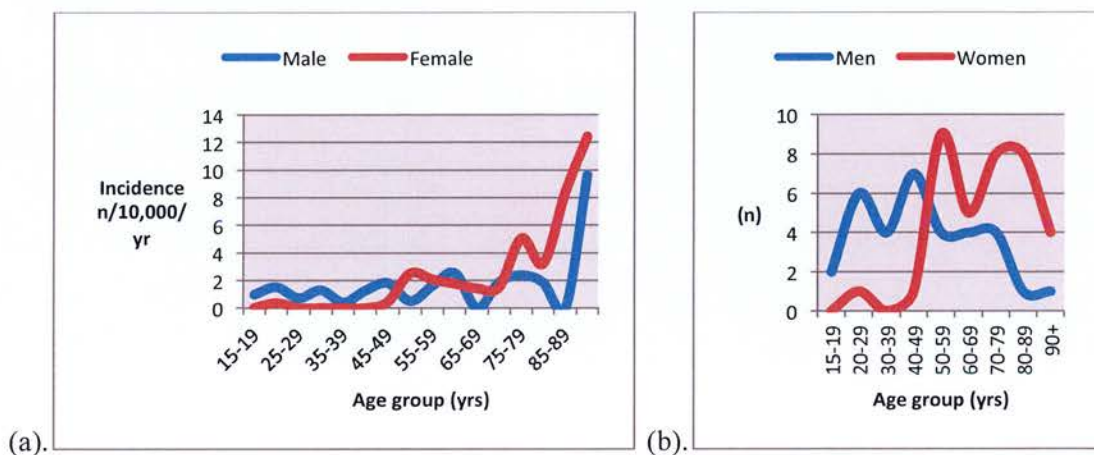


Figure 3.18 (a) The age- and gender-related *incidence* of humeral shaft fractures occurring in Edinburgh adults. (b) The actual *number* of humeral shaft fractures encountered, and presented according to patient age and gender.

Table 3.21 (next page) outlines the eight modes of injury responsible for 69 humeral shaft fractures. Notably, four fractures occurred by way of a ‘nil / spontaneous’ mechanism. These were pathological fractures through bone abnormally weakened by tumour. A simple fall from a standing height accounted for 62.3% of fractures, and this was the only group of patients where women outnumbered men. Aside from those suffering a pathological fracture, these patients were also the oldest. The average age of patients sustaining fracture from sporting activity, falls from height and RTAs was less than 40 years.

Injury mode	(n)	%	Age (yrs)	Gender ratio (M:F, %)	AO type (n)			% open
					A	B	C	
Simple fall	43	62.3	67.1	28:72	29	13	1	0
Sports-related	8	11.6	33.5	88:12	6	2	0	0
Direct blow	2	2.9	50.5	50:50	2	0	0	50.0
Other	4	5.8	60.8	75:25	3	1	0	0
RTA	3	4.3	40.0	100:0	3	0	0	0
Fall down stairs	3	4.3	57.0	100:0	0	2	1	0
Fall from a height	2	2.9	26.0	50:50	0	2	0	0
Nil / spontaneous	4	5.8	68.5	75:25	3	1	0	0
Total	69	100	59.6	48:52	46	21	2	1.4

Table 3.21 The number and proportion of humeral shaft fractures occurring in Edinburgh adults, according to the mode of injury responsible. The average age (mean) and gender ratio of patients involved is shown. The distribution of injuries according to AO fracture type is also given. (RTA = road traffic accident).

AO group	n (%)	Age (yrs)	M (n)	F (n)	% RTA / Height	% open	Fracture position (n, %)		
							Prox.	Middle	Distal
A1	34	63.0	15	19	0	0	15	10	9
A2	4	40.5	4	0	75.0	0	1	3	0
A3	8	53.9	6	2	0	12.5	1	6	1
% type A	(66.7)	59.5	25	21	6.5	2.2	17 (37.0)	19 (41.3)	10 (21.7)
B1	15	58.9	5	10	6.7	0	7	7	1
B2	4	63.8	1	3	25.0	0	1	2	1
B3	2	70.5	1	1	0	0	2	0	0
% type B	(30.4)	61.0	7	14	9.5	0	10 (47.6)	9 (42.9)	2 (9.5)
C1	0	-	-	-	-	-	-	-	-
C2	1	47	1	0	0	0	1	0	0
C3	1	51	0	1	0	0	0	1	0
% type C	(2.9)	49.0	1	1	0	0	1 (50.0)	1 (50.0)	0
Total	69	59.6	33	36	7.2	1.4	28 (40.6)	29 (42.0)	12 (17.4)

Table 3.22 The number and frequency of humeral shaft fracture types and groups, according to the AO classification system. The number and average age (mean) of men and women affected is shown. The proportion of open fractures and high energy injuries is also given. (RTA = road traffic accident; Height = fall from a height; Prox = proximal).

A relatively small sample size in relation to previous studies^{138, 139} precluded a detailed analysis of AO fracture subgroups, but the distribution of these is shown in Table 3.22, above. Fractures of the proximal and mid-diaphysis were most common. Simple fracture patterns (type A) predominated, and there was only one open fracture (sustained by a 55 year old woman following an assault). The majority (92.8%) of humeral shaft fractures presented as isolated injuries. In contrast to research from level one trauma centres in the United States⁹³, the frequency of high energy trauma (e.g. RTAs, falls from a height) was low.

3.6 Fractures around the elbow

Approximately five percent to seven percent of fractures in adults occur around the elbow joint^{132,142}. This group includes fractures affecting the distal humerus, proximal radius and proximal ulna. Impact testing in cadaveric specimens suggests that the patterns of fractures around the elbow are related to the elbow flexion angle at the time of injury¹⁴³. Radial head and coronoid fractures occur at flexion angles less than 80°, olecranon fractures occur following a fall onto the elbow at 90° of flexion and distal humeral fractures are seen when the flexion angle exceeds 110°.

Fractures around the elbow accounted for 9.8% of upper limb fractures and 6.4% of all fractures. A total of 405 elbow fractures were sustained by 382 patients, 54.4% of whom were women. For the purposes of analysis, any combination of ipsilateral elbow fractures was defined as a 'combined fracture', although bilateral elbow fractures were not included in this group. The frequency of open fractures was low (five patients, 1.3%). The distribution of fractures around the elbow, and the gender-related incidences, is shown in Table 3.23.

	Distal humerus	Proximal ulna	Proximal radius	Combined fractures**	p-value
Fractures (n, %)	46 (11.4)	66 (16.3)	263 (64.9)	30 (7.4)	-
Gender ratio (M:F, %)	35:65	47:53	47:53	33:67	p=0.087*
Incidence (n/10,000/yr)	0.8 (0.6-1.1)	1.2 (0.9-1.5)	4.8 (4.305-5.4)	0.3 (0.2-0.5)	-
Male	0.6 (0.3-1.0)	1.2 (0.8-1.7)	4.9 (4.1-5.8)	0.2 (0.1-0.5)	-
Female	1.0 (0.7-1.5)	1.2 (0.8-1.7)	4.8 (4.0-5.7)	0.3 (0.2-0.6)	-
Median age (yrs, IQR)	71.5 (36-83)	59 (36-75.5)	43 (28-56)	58 (30-85)	p<0.001 ^k
Men	28 (16-63)	53 (29-70)	51.5 (33-63)	42 (27-67.5)	p=0.207 ^k
Women	78.5 (62-85)	72 (42-78)	37 (23-47)	69.5 (49-86)	p<0.001 ^k
Mode of injury (n, %)					
Simple fall	34 (73.9)	43 (65.2)	145 (55.1)	21 (70.0)	p=0.017*
Sports-related	4 (8.7)	6 (9.1)	45 (17.1)	0	
Direct blow	1 (2.2)	4 (6.1)	6 (2.3)	2 (6.7)	
Other	3 (6.5)	1 (1.5)	10 (3.8)	1 (3.3)	
RTA	4 (8.7)	4 (6.1)	32 (12.2)	0	
Fall down stairs	0	5 (7.6)	11 (4.2)	4 (13.3)	
Fall from a height	0	3 (4.5)	14 (5.3)	2 (6.7)	
Open injuries (n, %)	0	3 (4.5)	0	4 (13.3)	p<0.001*

Table 3.23 The number and gender-related incidences of fractures around the elbow joint in the adult Edinburgh population. The age- and gender-related distribution of affected patients is shown. The responsible mode of injury is also provided. **includes all combined fractures of the ipsilateral elbow region. *Chi square test. ^kKW test. (RTA = road traffic accident).

Distal humerus

Fractures of the distal end of the humerus are important orthopaedic injuries, largely due to the challenge involved in managing them successfully. This is particularly true of the osteoporotic fracture types sustained by elderly adults¹⁴². The incidence of low energy distal humeral fractures in the elderly is increasing, although recent Finnish work suggests this trend may be stabilising^{144, 145}. Robinson *et al* examined the epidemiology of distal humeral fractures in Edinburgh adults between 1988 and 1997¹⁴⁶. They found a bimodal fracture distribution, a nearly equivalent ratio of men to women and an incidence of 0.57/10,000/yr.

The present series of adult fractures contained 46 isolated fractures of the distal humerus (and three further fractures sustained in combination with ipsilateral proximal radius fractures). The 46 isolated injuries represented 11.3% of elbow fractures, and 0.7% of all adult fractures. In contrast to Robinson's work¹⁴⁶ ten years previously, there was a marked female preponderance (65.2%). The overall incidence was approximately 50% higher (0.8/10,000/yr) with a higher incidence in women (1.0/10,000/yr) than in men (0.7/10,000/yr). A bimodal fracture distribution was seen when analysing fracture incidence and total fracture numbers (Fig. 3.19).

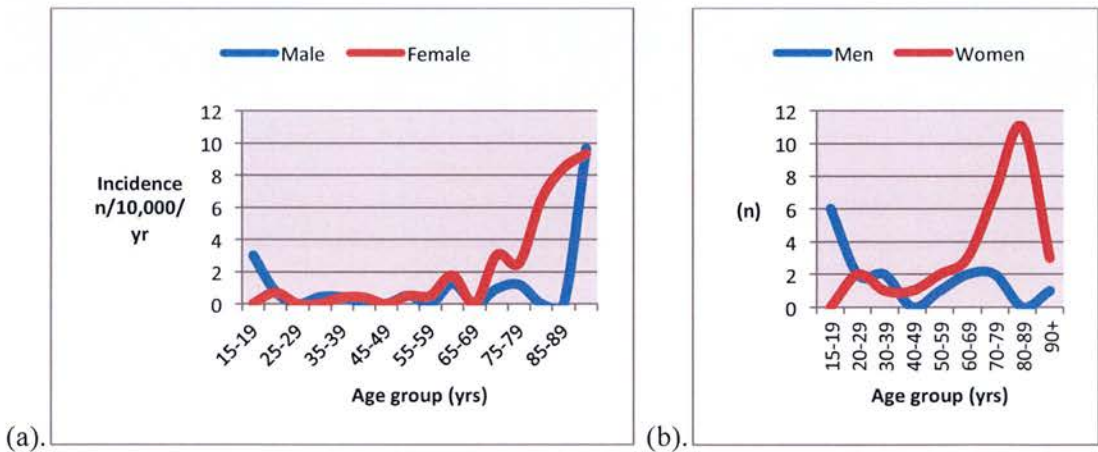


Figure 3.19 (a) The age- and gender-related *incidence* of isolated distal humeral fractures occurring in Edinburgh adults. (b) The actual *number* of distal humeral fractures encountered, and presented according to patient age and gender.

Two-thirds of fractures occurred in adults aged 55 years or older (n=30), and 83.3% of these patients were women. A simple fall from a standing height accounted for 90.0% of injuries in this older patient age group (Fig. 3.20, next page). In patients aged less than 55 years (n=16), 68.8% were men. While low energy injuries were also seen in this group (43.8%

were due to a simple fall), the remaining fractures occurred as a result of sporting activity, RTAs or a direct blow. There were no open fractures of the distal humerus.

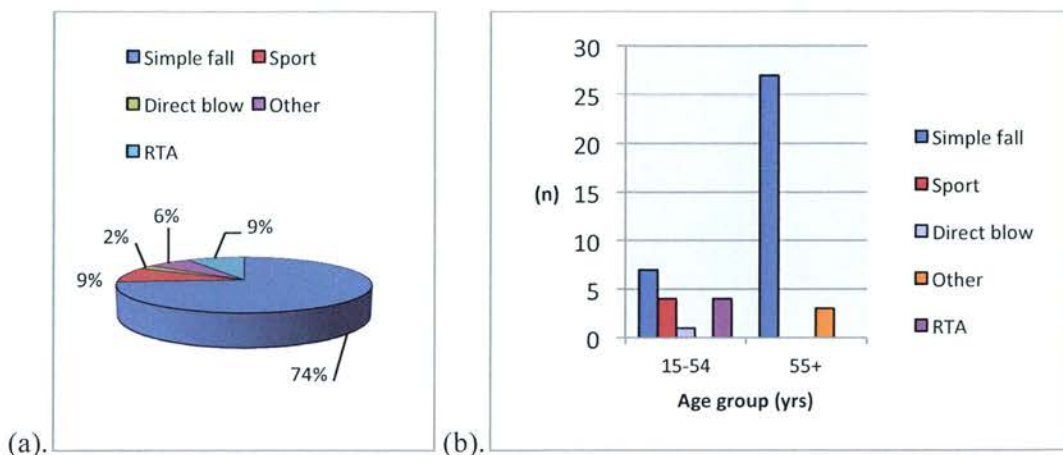


Figure 3.20 (a) The distribution of the modes of injury involved in causing isolated distal humeral fractures in Edinburgh adults. (b) The distribution of injury modes presented according to patient age group. (RTA = road traffic accident).

Early classification systems for distal humerus fractures were based on anatomic fracture location, and used terms such as supracondylar, intercondylar, T-type *etc.* Muller defined the boundaries of the distal humerus as “that part of the bone that lies within a square, whose base is the distance between the medial and lateral epicondyles, on an antero-posterior radiograph”¹³. The AO classification¹⁴ uses the familiar alphanumeric system to describe extra-articular (type A), partial articular (type B) and complete articular (type C) fractures. In a previous study of distal humerus fractures in Edinburgh adults, the authors used standard radiographs of the elbow, supplemented by intra-operative findings, to determine the frequency of the different fracture types¹⁴⁶: type A (38.7%), type B (24.1%) and type C (37.2%).

Notably, the present series was classified using radiographs alone (Table 3.24, next page). Type A fractures accounted for 69.6% of injuries. The 13-A2 subtype denotes simple extra-articular metaphyseal fractures. It accounted for 39% of all isolated distal humeral fractures, and occurred predominantly in older women. The 13-A1 subtype describes an apophyseal avulsion fracture of the lateral or medial epicondyle. This subtype was seen in 26%, and usually (83%) involved the medial epicondyle. These avulsions affected a young male patient group, and were occasionally associated with dislocation of the elbow joint.

Fracture groups	Number (%)	Mean age (yrs, range)	M (n)	F (n)	% with elbow dislocation	% from RTA / Height
A1	12	40.4 (15-90)	7	5	25.0	25.0
A2	18	78.7 (38-93)	4	14	0	0
A3	2	71.0 (57-85)	0	2	0	0
All type A	32 (69.6)	63.8 (15-93)	11	21	9.4	9.4
B1	3	36.0 (16-60)	3	0	0	0
B2	2	85.0 (82-88)	0	2	0	0
B3	5	48.4 (16-81)	1	4	0	20.0
All type B	10 (21.7)	52.0 (16-88)	4	6	0	10.0
C1	2	50.5 (22-79)	1	1	0	0
C2	2	55.0 (37-73)	0	2	0	0
C3	0	-	-	-	-	-
All type C	4 (8.7)	52.8 (22-79)	1	3	0	0
Total	46 (100)	60.3 (15-93)	16	30	6.5	8.7

Table 3.24 The number and frequency of isolated distal humeral fracture types and groups, according to the AO classification system. The number and age distribution of men and women affected is shown. The proportions of high energy injuries and fractures associated with an elbow dislocation are also given. (*M* = males; *F* = females; *RTA* = road traffic accident; *Height* = fall from a height).

Type B fractures accounted for 21.7%. They include partial articular fractures in either the sagittal (subtypes B1 and B2) or coronal (B3) planes. Sagittal plane fractures were originally classified by Milch³² as type I or type II, depending upon the involvement of the lateral portion of the trochlea. Five of these fractures were identified. 13-B3 coronal plane injuries involve a shear fracture of the capitellum (B3.1), trochlea (B3.2) or both (B3.3) and are rare injuries¹⁴⁷. Kocher, Lorenz, Hahn and Steintal were all involved in their original description³⁴⁻³⁷. Five capitellum fractures were seen, one of which also involved a section of the trochlea.

Only four (8.7%) type C fractures were identified during the one-year study period, and all occurred as a result of a low energy fall from a standing height. The frequency of these injuries was lower than previously recorded in the Edinburgh population. It is accepted that subtle intra-articular split fractures can be difficult to identify on plain radiographs and some injuries may have been missed. Supplemental information provided by intraoperative findings is likely to have improved the accuracy of classification for the previous Edinburgh report.

Proximal ulna

Injury to the proximal ulna can occur in isolation, or part of a more complex osseoligamentous injury pattern. These injuries often occur in patients with poor bone quality¹⁴⁸. The classification system proposed by the AO Foundation¹⁴ combines fractures of the proximal ulna with those of the proximal radius, and is not particularly useful in describing these injuries, guiding treatment or predicting outcome¹⁴⁸. Morrey has provided the Mayo classification of fractures of the olecranon process⁴⁷. It distinguishes three factors that have a direct influence on treatment: fracture displacement, comminution and ulnohumeral instability. Type 1 fractures are undisplaced. Type 2 fractures are displaced but the ulnohumeral joint is stable, and they may be simple (2A) or comminuted (2B). Mayo type 3 injuries are associated with joint instability. They may involve a simple (3A) or comminuted (3B) fracture but by definition are associated with ligamentous disruption (Fig. 3.21).

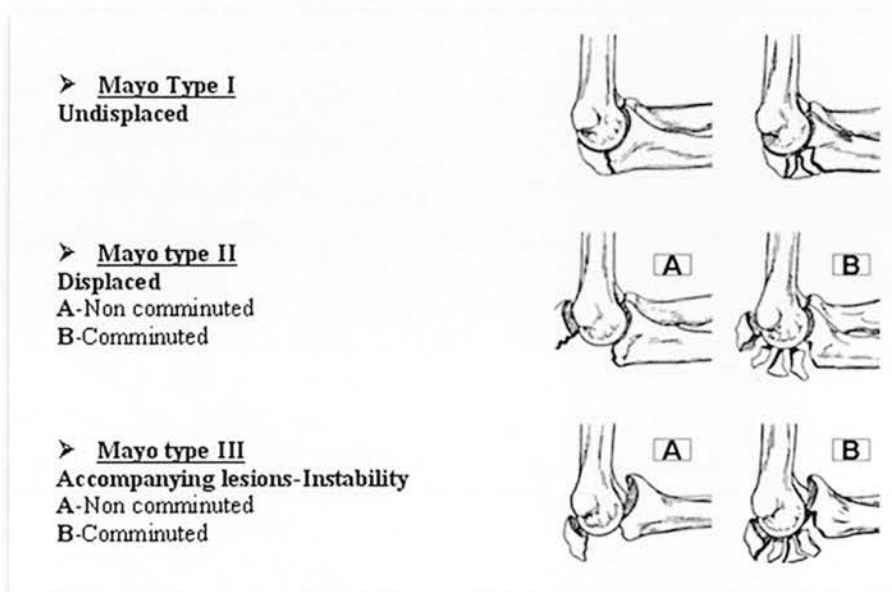


Figure 3.21 The Mayo classification of olecranon fractures⁴⁷. Types 1A and 1B are undisplaced, types 2A and 2B are displaced but the ulnohumeral joint is stable, and Types 3A and 3B are associated with joint instability. (Reproduced with permission from Elsevier Ltd.).

Regan and Morrey described a classification system for coronoid process fractures. Type I fractures involve a fracture at the tip of the process. Type II injuries involve a single or comminuted fragment involving up to 50% of the process. The result is that the height of the coronoid on a lateral radiograph is similar to that of the olecranon process. Type III fractures involve a single or comminuted fragment involving more than 50% of the process, such that coronoid height is lost (Fig. 3.22, next page).

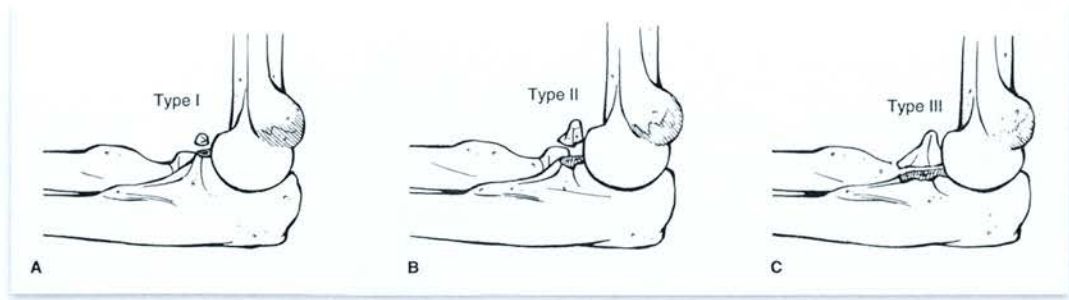


Figure 3.22 The Regan and Morrey classification of fractures of the coronoid process¹⁴⁹. Type I – an avulsion of the tip of the coronoid process. Type II – a single or comminuted fragment involving 50% of the process, or less. Type III – a single or comminuted fragment involving more than 50% of the process. (Reproduced with permission from Elsevier Ltd.).

There were 66 isolated fractures of the proximal ulna (and a further 13 ‘combined’ fractures sustained in association with other ipsilateral elbow fractures). Isolated fractures accounted for 16.5 % of elbow fractures and 1.1% of all adult fractures. There was an even distribution between men and women, with a similar incidence (1.2/10,000/yr). The median age for men was 50 yrs (IQR, 29-69); ten years older than for other elbow fractures. The median age of affected women was 72 years (IQR, 45-78). The fracture distribution curve shows a tendency to increased incidence in both men and women with advancing age, following a small peak in younger men (Fig. 3.24). This is a type G curve, according to Court-Brown and Caesar⁸⁸. The fracture *number* curve shows a distinct bimodal distribution in men.

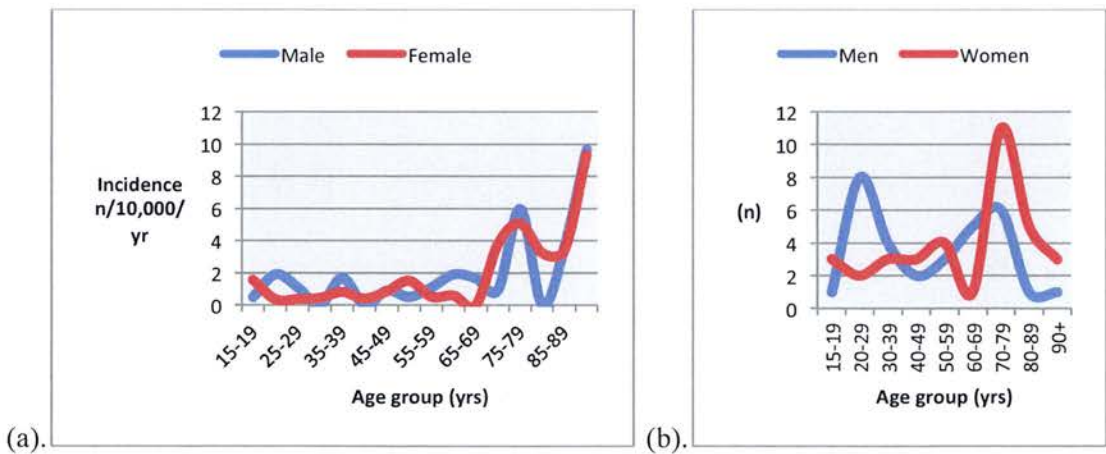


Figure 3.23 (a) The age- and gender-related *incidence* of isolated fractures of the proximal ulna occurring in Edinburgh adults. (b) The actual *number* of isolated proximal ulnar fractures encountered, and presented according to patient age and gender.

A simple fall from a standing height was responsible for the majority of injuries, irrespective of patient age group or the particular fracture subtype encountered (e.g. olecranon, coronoid, extra-articular avulsion). Simple fall fractures in younger adults (15 to 54 yrs) were evenly distributed between the genders, while female patients predominated (67.9%) in those aged 55 years or more. Sports-related fractures and those occurring as a result of a RTA were more commonly seen in patients aged 54 years or less.

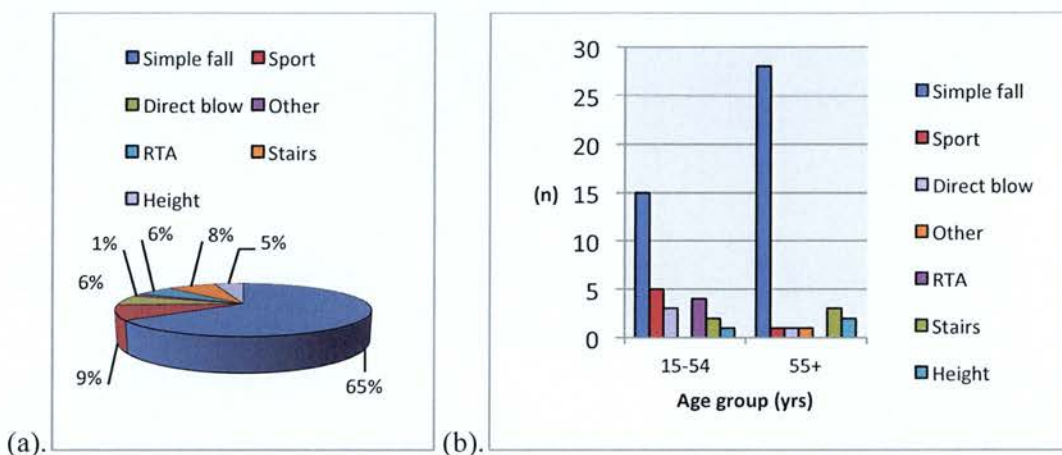


Figure 3.24 (a) The distribution of the modes of injury involved in causing isolated fractures of the proximal humerus in Edinburgh adults. (b) The distribution of injury modes presented according to patient age group. (RTA = road traffic accident; Stairs = fall down stairs; Height = fall from a height).

Table 3.25 (next page) shows the distribution of proximal ulna fractures. Despite the subcutaneous nature of the proximal ulna, only three open fractures (4.5%) were identified. Two involved the olecranon, but analysis of the third was not possible due to a lack of radiographs.

Fifty six fractures involved the olecranon. Twenty percent of these injuries were undisplaced (Mayo type 1), and approximately half of these involved comminution of the trochlear notch. The average age of affected patients was less than 50 years. Displaced fractures were more common, accounting for 80.4% of olecranon fractures. Associated ulnohumeral instability (Mayo type 3) was recognised in one patient. Despite displaced fractures occurring in an older patient group, there was no higher frequency of comminution. Three fractures involved the tip of the olecranon and were extra-articular. They occurred in elderly female patients.

Fractures of the coronoid process are reported to occur in 2% to 10% of patients who suffer a dislocation of the elbow. They may also present as isolated injuries, often following a subtle subluxation event¹⁴⁹. Current opinion would suggest that a varus posteromedial force produces a fracture of the tip of the coronoid (Regan and Morrey type I), whereas a posteriorly directed force can produce anything from a tip fracture to a single larger fragment (type II and III)¹⁴⁸. Seven of these injuries (10.8%) were noted, affecting patients with an average age of 45 years.

Subtype	(n)	(%)	Mean age (yrs, range)	M (n)	F (n)	% RTA / Height	% open fractures
Mayo 1A	8	12.3	47.3 (15-80)	3	5	12.5	0
1B	3	4.6	47.7 (21-75)	2	1	0	0
Mayo 2A	29	44.6	58.6 (16-97)	15	14	3.4	3.4
2B	15	23.1	60.6 (31-90)	5	10	20.0	0
Mayo 3A	0	-	-	-	-	-	-
3B	1	1.5	25	1	0	100	100
All olecranon	56	86.1	56.3 (15-97)	26	30	9.1	3.6
Type I	5	7.7	44.0 (18-68)	3	2	20.0	0
Type II	0	-	-	-	-	-	-
Type III	2	3.1	46.5 (29-64)	2	0	0	0
All coronoid	7	10.8	44.7 (18-68)	5	2	14.3	0
Extra-articular	3	3.1	77.0 (74-80)	0	3	0	0
All	66	100	55.7 (15-97)	31	35	10.8	3.1

Table 3.25 The number and frequency of proximal ulna fracture types, according to the Mayo and Regan and Morrey classification systems. The number and age distribution of men and women affected is shown. The proportion of high energy injuries and open fractures are also given. (*M* = males; *F* = females; *RTA* = road traffic accident; *Height* = fall from a height).

Proximal radius

Fractures of the proximal radius were originally reported as occurring almost exclusively in young men⁴⁴. More recent epidemiological work suggests this is no longer the case¹⁵⁰⁻¹⁵³. The original classification of radial head fractures was presented by Mason in 1954⁴⁴. He described undisplaced fractures (type 1), displaced partial articular head fractures (type 2) and comminuted fractures of the entire head (type 3). He did not include radial neck fractures. Johnston proposed a fourth type: those fractures associated with a dislocation of the elbow¹⁵⁴. Morrey modified the four-part system to include radial neck fractures⁴⁵, although some authors suggest these injuries have different management issues and should be considered separately¹⁴⁸.

In a study from the United States, van Riet *et al* reported on 333 radial head fractures in adults from 1997 to 2002¹⁵³. The mean age of the patients was 45 years and there were 223

(67%) Mason type 1, 46 Mason type 2 (14%) and 64 (19%) Mason type 3 fractures. A total of 118 (39%) had associated fractures or soft tissue injury (including coronoid fractures and elbow dislocations). Kaas and colleagues retrospectively reviewed a series of Dutch patients between 2006 and 2008, and found an incidence of 2.8/10,000/yr¹⁵¹. Women accounted for approximately 60% of patients, and represented an older cohort (mean age 52.8 yrs) when compared with men (mean 40.5 yrs). The reported frequency of associated osseous injury was 12.4%.

Isolated radial head and neck fractures accounted for 263 (64.9%) fractures around the elbow in the present series. (An additional 15 fractures were noted in the combined elbow fractures group). Seven cases of bilateral proximal radial fracture were encountered (four men, three women) and one male patient suffered a recurrent radial head fracture several months after his index injury. The median age of all patients was 43 years (R 15-87 yrs, IQR 28-56 yrs). One hundred and twenty six fractures occurred in 121 men (47.4%) with a median age of 37 years (R 15-81 yrs, IQR 23-47 yrs). Women (n=134) had a median age of 51 years (R 15-87 yrs, IQR 33-62.5 yrs). Proximal radial fractures accounted for 3.8% of all fractures and 6.3% of upper limb fractures. The incidence was 4.8/10,000/yr overall (95% CI, 4.3-5.4) and was similar in both sexes (Table 3.26). The distribution curves (Fig. 3.25) confirm that men and women present at different ages, with the peak in female age-related incidence occurring 20 to 30 years later than that in men.

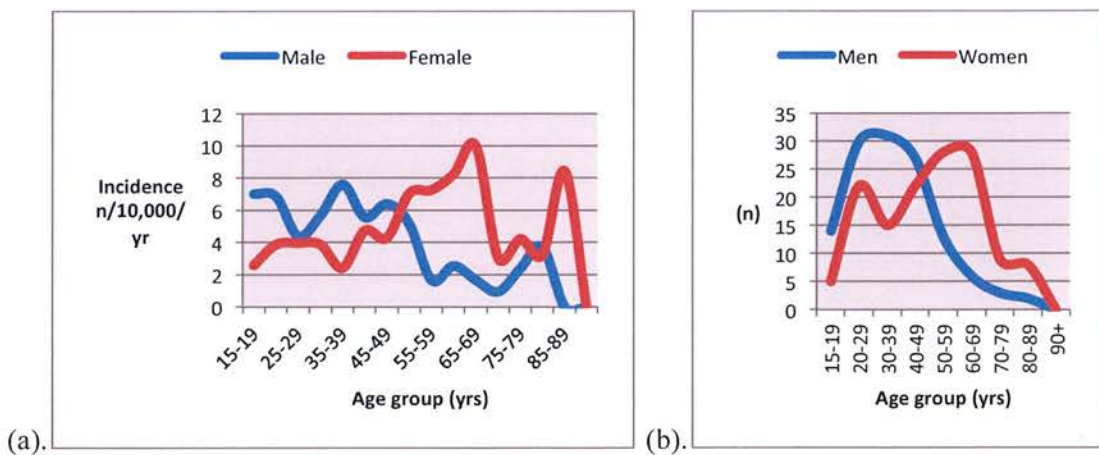


Figure 3.25 (a) The age- and gender-related *incidence* of isolated fractures of the proximal radius occurring in Edinburgh adults. (b) The actual *number* of isolated proximal radial fractures encountered, and presented according to patient age and gender.

Table 3.26 shows the gender distribution of injury modes responsible for proximal radial fractures. In men, the frequency of high energy injuries (RTAs, falls from a height, sports-related injury) was significantly more common than in the female group ($p < 0.001$, Chi square test). A simple fall from a standing height accounted for 73.0% of fractures in female patients and 87.7% of fractures in all patients aged 55 years or more, irrespective of gender. Sports-related proximal radial fractures occurred in an exclusively young adult group with a median age of 26 years (R 15-51 yrs, IQR 20-37 yrs) and 73.3% were men. A total of 32 fractures occurred as a consequence of a RTA, and 28 (87.5%) of these were sustained by injured pedal cyclists.

	Men (n=121)	Women (n=134)	All (n=255)	p-value
Fracture incidence (n/10,000/yr, 95% CIs)	4.9 (4.0-5.8)	4.8 (4.0-5.7)	4.8 (4.3-5.4)	-
Median age (yrs, IQR)	37 (23-47)	52 (33-63)	43 (28-56)	$p < 0.001^{**}$
Mode of injury (n, %)				$p < 0.001^*$
Simple fall	45 (36)	100 (73)	145 (55)	
Sports-related	33 (26)	12 (9)	45 (17)	
Direct blow	4 (3)	2 (1.5)	6 (2)	
Other	4 (3)	6 (4)	10 (4)	
RTA	22 (17)	10 (7)	32 (12)	
Fall down stairs	6 (5)	5 (4)	11 (4)	
Fall from a height	12 (10)	2 (1.5)	14 (5)	

Table 3.26 The gender-related differences in age, incidence and mode of injury for isolated proximal radial fractures in Edinburgh adults. *Chi square test. **MWU test. 'p-values' have been calculated for comparisons between the genders. (RTA = road traffic accident).

Isolated radial head fractures outnumbered those of the radial neck by approximately 2:1, although the patient gender ratios were similar (Table 3.27, next page). A greater proportion of radial head fractures were associated with more complex injury patterns (according to the Mason classification), but the frequency of patients with associated fractures was similar for both fracture subtypes.

	Radial head	Radial neck	p-value
Fractures (n, %)	180 (68.4)	83 (31.6)	-
Gender ratio (M:F, %)	49:51	45:55	p=0.71*
Incidence (n/10,000/yr, 95% CIs)	3.3 (2.8-3.8)	1.5 (1.2-1.9)	-
Median age (yrs, IQR)	43 (28-55)	41 (27-61)	p=0.86**
Mode of injury (n, %)			p<0.001*
Simple fall	105 (58)	40 (48)	
Sports-related	25 (14)	20 (24)	
Direct blow	5 (3)	1 (1)	
Other	6 (3)	4 (5)	
RTA	19 (11)	13 (16)	
Fall down stairs Fall from a height	7 (4) 13 (7)	4 (5) 1 (1)	
Mason classification (n, %)			p<0.001*
Type 1	125 (70)	81 (98)	
Type 2	38 (21)	1 (1)	
Type 3	9 (5)	-	
Type 4	8 (4)	1 (1)	

Table 3.27 The number, frequency and incidence of isolated radial head and radial neck fractures encountered in Edinburgh adults. The age- and gender-related distribution of those affected is shown. The responsible modes of injury and distribution of fractures according to the modified Mason classification system are also given. *Chi square test. **MWU test. (RTA = road traffic accident).

Combined elbow fractures and associated injuries

The literature suggests that the frequency of associated soft tissue and / or osseous injury at the time of proximal radial fracture ranges from 12% to 39%^{151, 153}. In this series, combined elbow fractures included all fractures in the ipsilateral elbow occurring as a result of the same injury event, and represented 7.4% of all elbow fractures. Thirty combined elbow fractures were sustained by 15 patients as a result of 15 accidents. The proximal radius was involved in each case (14 radial head and one radial neck fracture). The associated injuries involved the olecranon (n=4), coronoid process (n=4), olecranon plus coronoid (n=2), distal humerus (n=3) and fracture of the ulnar shaft just distal to the coronoid (n=2).

Ten combined elbow fractures involved women (median age 66 years, R 20-94 yrs, IQR 55-78) and five occurred in men (median age 42 years, R 25-85 yrs, IQR 29-50 yrs). Despite the observed difference in median age between the sexes, the result did not reach statistical significance (p=0.28, MWU test). Seven of the 15 (46.7%) patients sustaining combined elbow fractures had suffered an elbow dislocation. There were nine elbow dislocations seen in the isolated proximal radial fracture group (the Mason type 4 injuries). Therefore, the frequency of elbow dislocation with all proximal radial fractures in this series was 5.8%.

Thirty two of 263 (12.2%) isolated proximal radial fractures, and four of 30 (13.3%) combined elbow fractures, were associated with fractures elsewhere. When proximal radial fractures were analysed according to Mason's classification (Table 3.28), the frequency of associated fractures increased from 14.4% in type 1 injuries to 47.1% in type 4 injuries.

	Mason 1	Mason 2	Mason 3	Mason 4	p-value
Fractures (n, %)	209 (74.9)	42 (15.1)	11 (3.9)	17 (6.1)	-
Gender ratio (M:F, %)	48:52	50:50	64:36	53:47	$p=0.76^*$
% associated fractures	14.4	14.3	36.4	47.1	$p=0.002^*$

Table 3.28 The frequency of associated fractures, sustained in addition to proximal radial fractures, stratified according to the modified Mason classification system⁴⁵. *Chi square test.

3.7 Forearm diaphyseal fractures

The forearm plays an important role in upper extremity function. The presence of the proximal and distal radio-ulnar joints allows supination and pronation of the radial shaft over the ulna, and the forearm bones also serve as the origin for many muscles passing into the hand.

Fractures of the forearm may involve the diaphyses of both radius and ulna, or either bone in isolation. Associated disruption of the distal radio-ulnar joint (DRUJ), or a dislocation of the radial head may also occur. A Galeazzi injury is a fracture of the shaft of the radius with a dislocation of the DRUJ³⁶, and was first described in 1934. This injury has since been further classified by Rettig and Raskin⁴³. A special type of Galeazzi injury may occur whereby the diaphyses of both forearm bones are fractured, and this injury type is said to result from high energy trauma¹⁵⁵. Fracture of the proximal ulna with dislocation of the radial head was first described by Monteggia in 1814, and was classified by Bado in 1967⁴⁶. The Monteggia variant whereby a proximal ulna shaft fracture occurs in combination with proximal *and* distal radio-ulnar joint dissociation has been described, but is exceedingly rare^{156, 157}. Forearm injury involving complete radio-ulnar dissociation (as described by Essex-Lopresti¹⁵⁸) commonly results from high energy trauma, but may also be seen following low energy violence^{157, 159}.

There is limited historical data on the overall rates of fracture of the forearm diaphyses in adults. Previous studies have combined them with fractures of the distal radius and / or proximal forearm when they are clearly very different injuries^{87, 90}. Brinker and O'Connor reported an incidence of 21.4/10,000/member-years in their analysis of children and adults in Texas, United States⁹³. However, this reported incidence of 'forearm' fractures was five times higher than that reported for 'wrist' fractures. It is assumed that the authors also included distal radial fractures in the former category.

Court-Brown and Caesar reported on both bone fractures, isolated radius and isolated ulna fractures in Edinburgh adults in 2000⁸⁸. They noted all three subtypes to occur predominantly in young men, but there was an increased older female incidence in the isolated radius or ulna subtypes.

Isolated ulnar shaft fractures are often caused by direct violence, being referred to as ‘nightstick’ injuries under those circumstances. They have traditionally been associated with young male adults^{160, 161}. McQueen reviewed isolated ulnar shaft fractures in Edinburgh adults from 1990 to 1992¹⁶². A direct blow was responsible for 38%, a simple fall from a standing height for 31% and pedestrian RTAs for 14%. Men were more commonly affected (63%) than women, but there was a tendency towards increased incidence in older women.

The present series contained 68 forearm fractures occurring in 68 patients. The median age of all patients was 25.5 years (IQR, 19-54 yrs) with a range from 15 to 89 years. Fifty three patients were male (77.9%) with a median age of 23 years (IQR 17-30 yrs). Female patients constituted an older group; 15 (22.1%) were affected with a median age of 60 years (IQR 37-80.5 yrs). Forearm fractures accounted for 1.0% of all fractures and 1.6% of upper limb fractures. The overall incidence was 1.2/10,000/yr (95% CI, 1.0-1.6) and was higher in men (2.0/10,000/yr, 95% CI 1.5-2.7) than in women (0.5/10,000/yr, 95% CI 0.3-0.9). The relevant fracture curves are shown below (Fig. 3.26). Seven of 68 (10.3%) forearm fractures were open injuries: two grade 2 and five grade 1. The ulna was involved in all cases of open fracture. No open injuries were seen where the radius was fractured in isolation. No open injuries were seen where the radius was fractured in isolation.

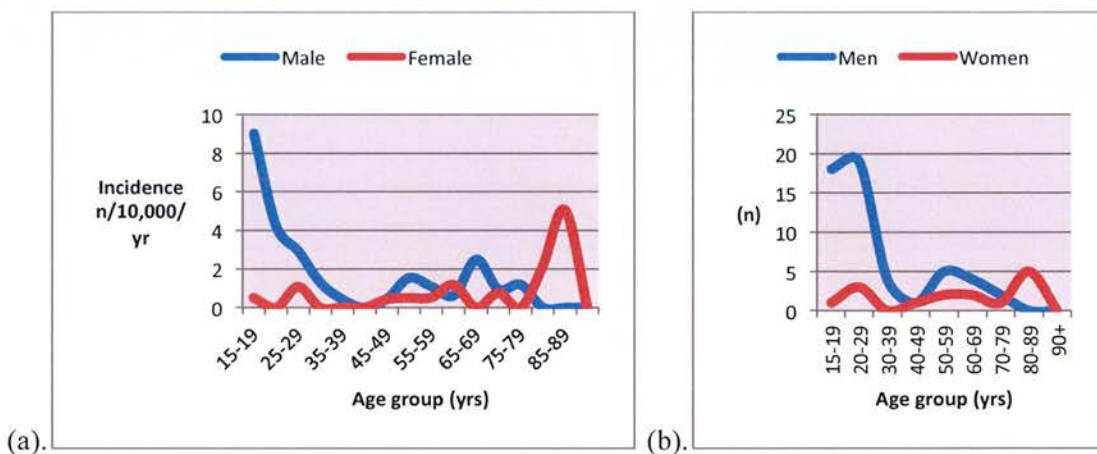


Figure 3.26 (a) The age- and gender-related *incidence* of forearm fractures occurring in Edinburgh adults. (b) The actual *number* of forearm fractures encountered, and presented according to patient age and gender.

Seven modes of injury were identified as being responsible for forearm fractures (Fig. 3.27). High energy mechanisms such as RTAs and falls from a height caused 21.2% of fractures. The frequency was higher (23.5%) in patients aged younger than 55 years, than in older patients (11.8%), and was higher in men (22.6%) than in women (13.3%). Sports-related injury was the commonest mode of injury in young adults, while a simple fall from a standing height was responsible for the majority (52.9%) of fractures in the older age group.

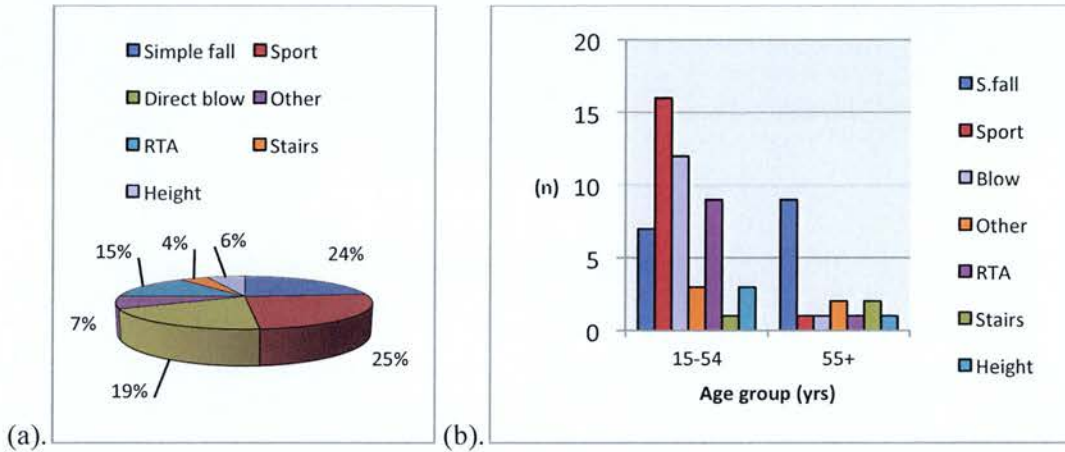


Figure 3.27 (a) The distribution of the modes of injury involved in causing forearm fractures in Edinburgh adults. (b) The distribution of injury modes presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from a height).

Thirteen (19.1%) forearm fractures involved injury to both bones (Table 3.29, next page). One injury involved associated DRUJ dislocation. The majority of cases involved moderate to high energy transfer, and one-quarter were open injuries. Fractures of the radius alone accounted for a similar proportion of patients (20.6%) but were associated with a significantly lower median age. Moderate to high energy transfer was responsible for the majority of these cases, and the frequency of Galeazzi injuries was 14.3%. An isolated fracture of the ulna was the commonest subtype encountered (n=41, 60.3%). Patients in this group were significantly older than those in the other two groups. The frequency of Monteggia injuries was 14.6%, and half of these were open.

	Both bones	Radius only	Ulna only	p-value
Fractures (n, %)	13 (19.1)	14 (20.6)	41 (60.3)	-
Gender ratio (M:F, %)	77:23	93:7	73:27	p=0.307*
Incidence (n/10,000/yr, 95% CIs)	0.2 (0.1-0.4)	0.3 (0.1-0.4)	0.8 (0.5-1.0)	-
Median age (yrs, IQR)	25 (15.5-40.5)	16 (15-23)	30 (23-63)	p<0.001 ^k
Mode of injury (n, %)				
Simple fall	3 (23.1)	3 (21.4)	10 (24.4)	p=0.043*
Sports-related	4 (30.8)	7 (50.0)	6 (14.6)	
Direct blow	2 (15.4)	1 (7.1)	10 (24.4)	
Other	0	0	5 (12.2)	
RTA	1 (7.7)	3 (21.4)	6 (14.6)	
Fall down stairs	0	0	3 (7.3)	
Fall from a height	3 (23.1)	0	1 (2.4)	
Open injuries (n, %)	3 (23.1)	0	4 (9.8)	p=0.141*
Galeazzi (n, %)	1 (7.7)	2 (14.3)	-	-
Monteggia (n, %)	-	-	6 (14.6)	-

Table 3.29 The number, frequency and incidence of forearm diaphyseal fractures in Edinburgh adults. The age- and gender-related distribution of affected patients is shown, as is the responsible mode of injury. The frequency of open injuries, Galeazzi variants, and Monteggia variants is also given. *Chi square test. ^kKW test. (RTA = road traffic accident).

3.8 Fractures of the distal radius and ulna

Distal radius

Fractures of the distal radius are one of the most common fracture types encountered in orthopaedic surgery^{84, 86, 89, 93, 132, 163, 164}. In this series, 1,124 distal radial fractures occurred in 1,108 patients. Fifteen patients suffered bilateral fractures and one patient suffered a second distal radial fracture several months after the index fracture. The median age of all patients was 62 years (IQR, 37-76 yrs), with a range from 15 to 98 years. Seven hundred and eighty nine fractures (70.2%) affected female patients, and 335 (28.8%) occurred in men. The median age of female patients was 68 years (IQR, 54-79 yrs). Men were significantly younger with a median age of 34 years (IQR, 20-59 yrs), ($p < 0.001$, MWU test).

Distal radial fractures accounted for 16.4% of all acute fractures seen during the study period and were the commonest single fracture. They made up 71.0% of all forearm fractures and 27.1% of upper limb fractures. The overall incidence was 20.6 /10,000/yr (95% CI, 19.5-21.9). The incidence in women (27.7/10,000/yr, CI 25.8-29.7) was more than twice that of men (13.0/10,000/yr, CI 11.6-14.4). A bimodal fracture distribution was seen in male patients. Fractures occurred in men aged 15 to 24 years before a gradual rise in age-related male incidence affecting elderly men (Fig. 3.28). In younger women the incidence was much lower than that of men, but increased dramatically in the post-menopausal age groups. The curve is type G, as described by Court-Brown and Caesar⁸⁸.

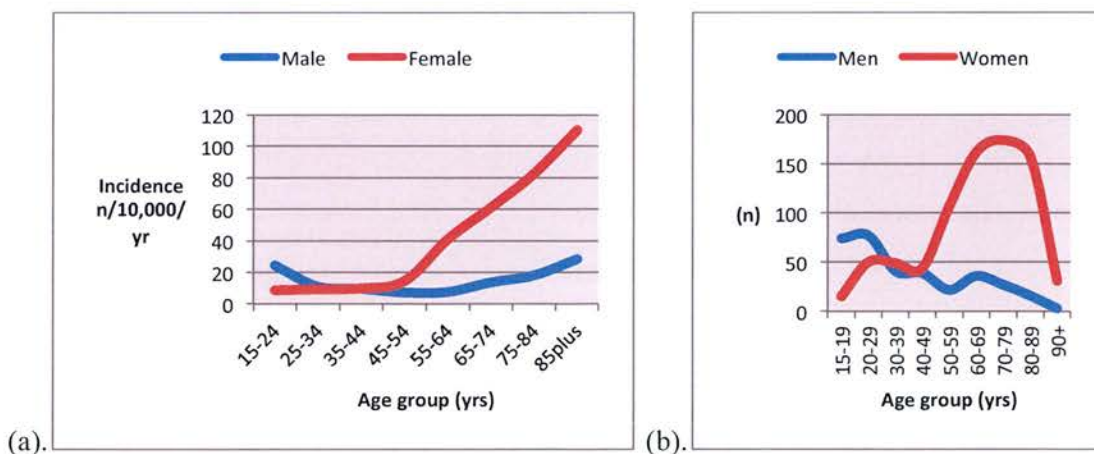


Figure 3.28 (a) The age- and gender-related *incidence* of distal radial fractures occurring in Edinburgh adults. (b) The actual *number* of distal radial fractures encountered, and presented according to patient age and gender.

In female patients, the age- and gender-related incidence of distal radial fractures rose sharply and steadily from 10/10,000/yr in those aged 55 years or less to 117/10,000/yr in women over 85 years of age. This postmenopausal rise is well documented in the literature^{86, 132, 134, 165-176}. A rise in incidence was also seen in elderly men, but occurred later in life and was less pronounced. A small number of previous studies have shown a similar trend^{168, 171}.

Distal radial fractures were more commonly seen during the winter months, with a higher proportion occurring in patients aged 55 years and older (Fig. 3.29). This is a finding common to northern countries where ice or snow is a frequent cause of falls^{173, 177}. Injury to younger patient age groups occurred more commonly during the spring and summer months.

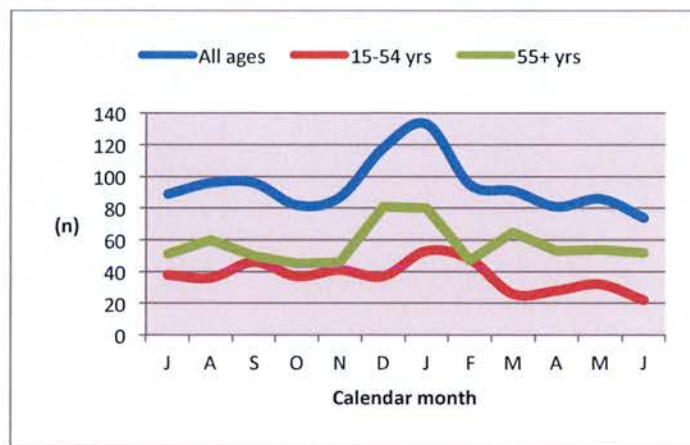


Figure 3.29 The seasonal and age-related distribution of distal radial fractures, occurring in Edinburgh adults. The total number of fractures is shown, as well as the number affecting younger and older adults.

A simple fall from a standing height caused 766 (68.1%) distal radial fractures. Affected patients had a median age of 69 years (IQR, 57-80 yrs) and 85% were women. Sporting injury accounted for 167 (14.9%) injuries. Three-quarters of these fractures affected men, and the median age was much younger at 27 years (IQR, 19-39 yrs). Falling down stairs caused 52 fractures, three-quarters affecting women with a median age of 59.5 years (IQR, 36-74 yrs). Road traffic accidents accounted for 35 injuries. Both sexes were affected in similar numbers and one-third occurred in pedal cyclists. The median age of those affected was 37 years (IQR, 24-51 yrs). Falls from a height caused 32 fractures. There was a male preponderance (75.0%) and a median age of 43 years (IQR, 24-56 yrs). Smaller numbers of fractures were caused by direct blows and other injury modes.

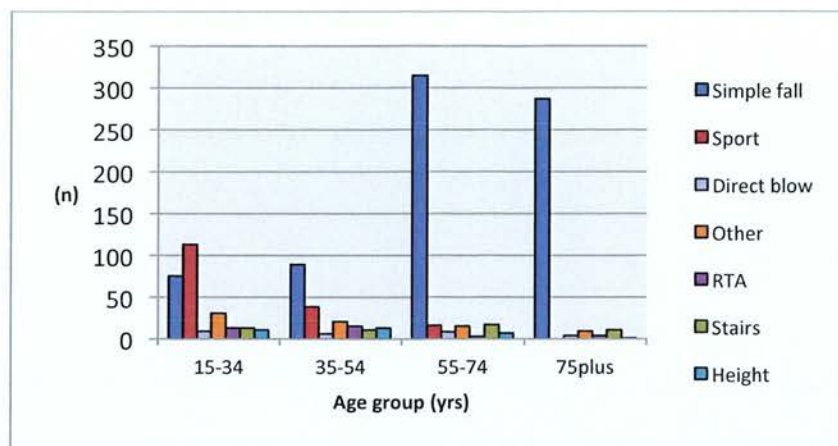


Figure 3.30 The distribution of the modes of injury involved in causing distal radial fractures in Edinburgh adults, and presented according to patient age group. (*RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from a height).

Figure 3.30 shows that low energy mechanisms, such as falls from a standing height, were the predominant cause of distal radial fractures in patients aged 55 years and older. High energy mechanisms such as RTAs and falls from a height were relatively uncommon in this group (2.2%). In patients aged 75 years and older, 89.9% of simple fall fractures occurred in women. Simple falls were also seen in patients younger than 55 years but accounted for only 36.7% of fractures, while the proportion of fractures from RTAs and falls from a height increased (11.8%). Sports-related fractures of the distal radius were almost exclusively seen in young adults. In patients aged 15 to 34 years, 82.5% of sports-related fractures occurred in men.

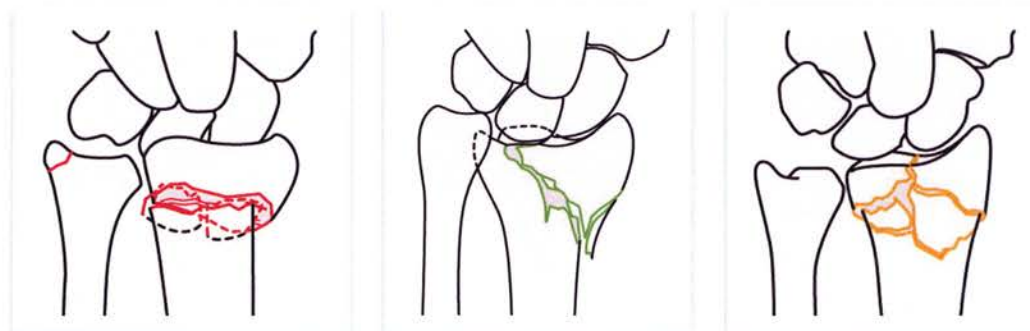


Figure 3.31 The classification of distal radius fracture types as described by the AO Foundation¹³ and the OTA¹⁴. From left to right: an extra-articular type A fracture; a partial articular type B fracture; a complete articular type C fracture. (Reproduced with permission from the AO Foundation).

The classification system described by the AO Foundation¹³, and later modified by the OTA¹⁴, describes extra-articular, partial articular and complete articular fractures of the distal radius as types A, B and C, respectively. Illustrative examples of each fracture type are shown in Figure 3.31 (previous page).

Type A fractures accounted for 59.6% (n=670) of injuries. The majority of fractures (72.8%) affected women whose median age was 63 years (IQR, 36-77 yrs). Of note, group A1 fractures involve fracture of the distal ulna only and were not included in the distal radial fracture analysis. Type B fractures were less common (16.1%, n=181). Fifty six percent affected women, and the median age of affected patients was 56 years (IQR, 33-72 yrs). Type C fractures affected 23.1% (n=260) of patients, with a female preponderance (73.1%) and a median patient age of 63 years (IQR, 42-77 yrs).

Data on the radiographic integrity of the ulnar styloid process, and ulnar head or neck, were available for 1,090 (97.0%) fractures. Type B fractures were associated with the lowest frequency of ulnar styloid injury (Table 3.30). The highest frequency of ulnar styloid fractures was seen with type C fractures of the distal radius.

	AO fracture type			p-value
	A	B	C	
No styloid fracture	300 (45.8)	136 (76.0)	70 (27.3)	p<0.001*
Styloid fracture	314 (47.9)	41 (22.9)	171 (66.8)	
Ulnar head / neck fracture	41 (6.3)	2 (1.1)	15 (5.9)	
Total (n, %)	655	179	256	-

Table 3.30 The number and frequency of distal ulna fractures, occurring in association with fractures of the distal radius in Edinburgh adults, according to AO fracture type. *Chi square test.

When low energy simple fall injuries were analysed, type C distal radius fractures accounted for a greater proportion of fractures in the older patient age groups (Fig. 3.32). Type B fractures were more frequently seen in younger patient groups. When analysing the demographics for high energy injuries, the opposite trend was seen: type C fractures made up a greater proportion of the injuries seen in young adults, and type B fractures became increasing common with advancing patient age. Type A fractures were the most frequently encountered fracture type in all age groups, irrespective of the injury mode involved.

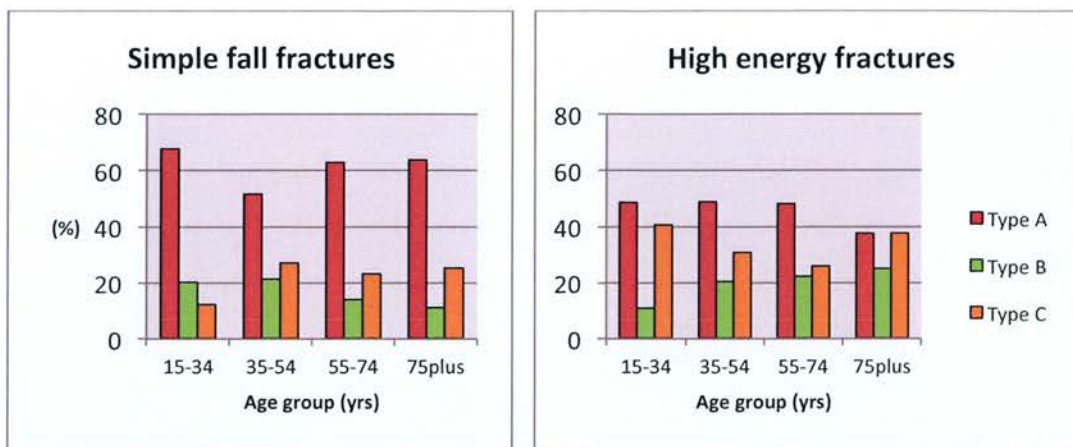


Figure 3.32 The proportion of AO type A, B, and C distal radial fracture types sustained by Edinburgh adults, and arranged according to patient age group. The graph on the *left* refers to those injuries resulting from a simple fall from standing height. The graph on the *right* depicts those injuries resulting from high energy trauma (road traffic accidents and falls from height).

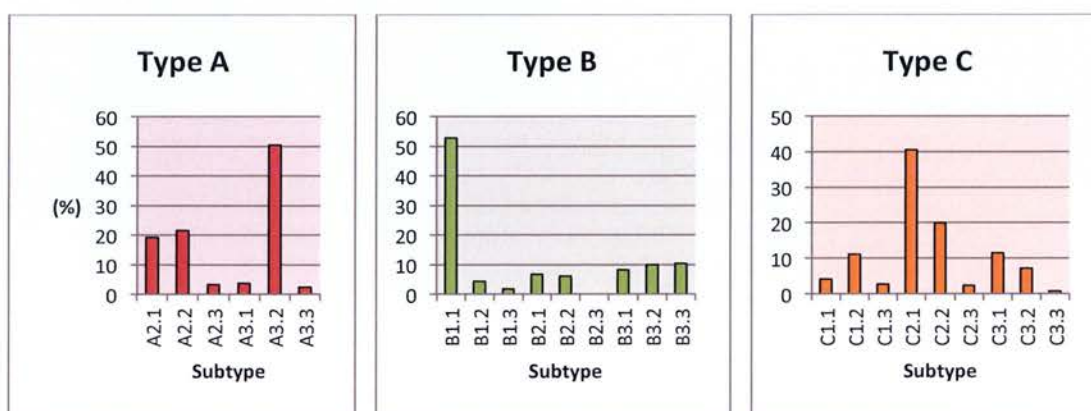


Figure 3.33 The distribution of distal radial fracture subtypes, classified according to the AO system, and occurring in Edinburgh adults. The three graphs represent AO types A, B, and C fractures, and the relative proportion of subtypes *within* each broad AO category.

Figure 3.33 indicates that the commonest AO subtypes encountered were A3.2 (337 fractures), A2.2 (n=143), A2.1 (n=128), C2.1 (n=105) and B1.1 (n=95). The age- and gender-related distribution for each of these subtypes is shown below (Fig. 3.34). The C3.2 subtype is also shown, as this is generally considered to represent the severe articular fracture.

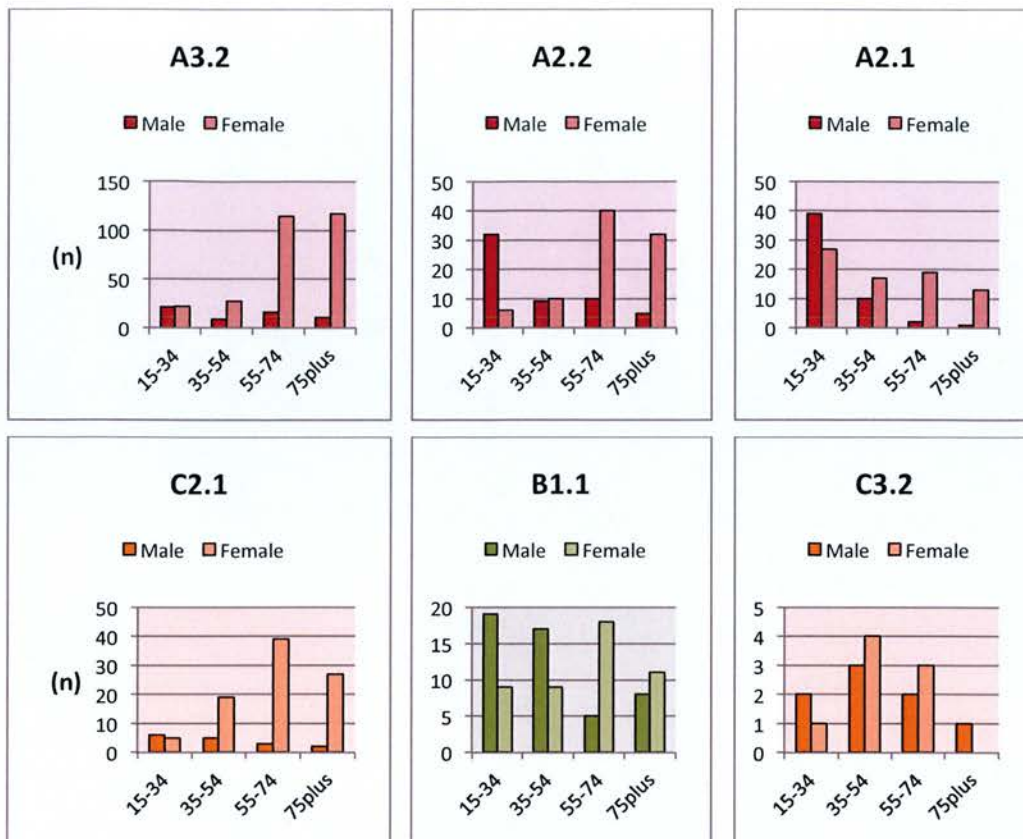


Figure 3.34 The number and age- and gender-related distribution of selected AO distal radial fracture subtypes, occurring in Edinburgh adults. Patient age groups are presented in years.

Certain common fracture subtypes occurred in distinct patient groups. Fracture involving comminution of the distal radial metaphysis (subtypes A3.2 and C2.1) occurred predominantly in older women, displaying a Court-Brown and Caesar¹³² type E fracture distribution. Together these two fracture types comprised 39.3% of distal radial fractures. The A2.2 (simple metaphyseal with dorsal displacement) and B1.1 (radial styloid) fractures were seen in young men as well as older women, resembling a type A fracture distribution. Simple extra-articular fractures without metaphyseal comminution and without displacement (A2.1) were more commonly seen in young men and women.

Eight open fractures of the distal radius were seen (Table 3.31, next page). Six were classified as Gustilo and Anderson¹¹² grade 1, with a small (<1cm) skin laceration. Four of these fractures were AO type C injuries. Two Gustilo grade 2 injuries resulted in type A fractures with a skin laceration >1cm in length. All open fractures resulted from low energy trauma, affecting patients with a median age of 58.6 years. Metaphyseal comminution was

present in all open distal radius fractures. In two cases, the metaphyseal comminution extended into the radial diaphysis.

Patient age and gender	AO subtype	Gustilo grade	Injury mode
65 F	C2.2	1	Simple fall
18 M	A3.2	2	Unknown
87 F	A3.2	1	Simple fall
63 M	A3.3	2	Simple fall
46 F	C2.1	1	Simple fall
62 F	A3.2	1	Simple fall
53 F	C2.3	1	Simple fall
75 F	C3.2	1	Simple fall

Table 3.31 The classification of the eight open fractures of the distal radius, sustained by Edinburgh adults, and presented according to AO and Gustilo classification systems. The age and gender of those affected is given, together with the mode of injury responsible. (*M* = male; *F* = female)

Distal ulna

Fractures of the distal radius are often associated with a fracture of the ulnar styloid, as described above. Associated fractures of the distal ulnar metaphysis are less common. Their frequency in the present series ($n=58$, 5.3%) matches that reported by Biyani *et al* in 1995 (19 of 320 fractures, 5.9%)¹⁷⁸. Less frequently reported are isolated fractures of the distal ulna, occurring in the absence of any fracture of the radius. This is possibly due to many of these injuries simply representing the most distal variation of the isolated ulnar diaphyseal fracture. In a manner similar to that employed by Muller in his definition of the distal humerus¹³, the boundaries of the distal radius and ulna are the parts of the bones that lie within a square, whose base is the distance between the radial and ulnar styloids, on an anteroposterior radiograph.

Thirty four fractures of the distal ulna were sustained by 33 patients, representing 0.5% of all fractures and 0.8% of upper limb fractures. One male patient suffered bilateral injuries as the result of an assault. There were no open fractures. Twenty men were affected with a median age of 29 years (IQR 20-43 yrs), range 15 to 88 years. Affected women ($n=13$) were significantly older with a median age of 74 years (IQR 62-85 yrs), range 52 to 92 years ($p<0.001$, MWU). The pattern of injury modes seen varied significantly between younger and older patient age groups ($p<0.001$, Chi square). In adults younger than 55 years, three-fifths of fractures were caused by sport or a direct blow. In older patients a simple fall caused 71.4% of injuries (Fig. 3.35).

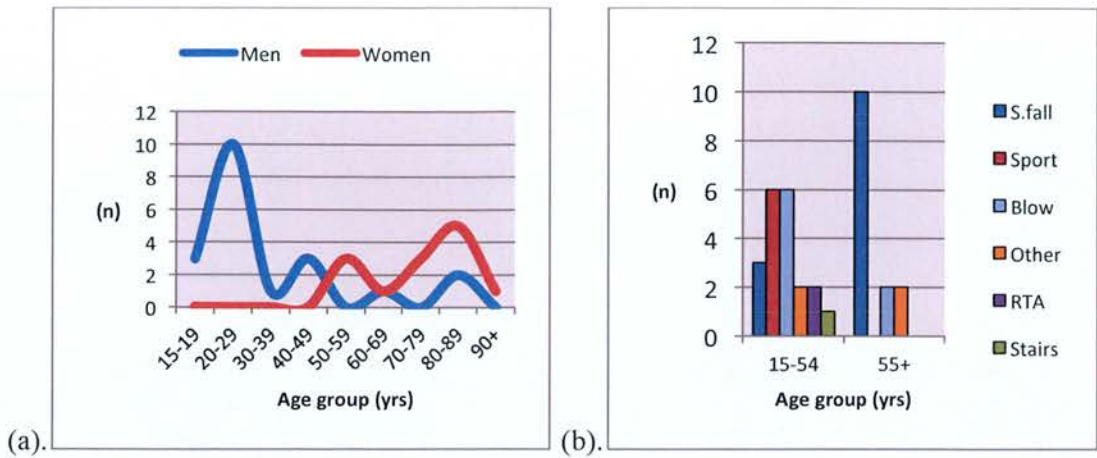


Figure 3.35 (a) The *number* of fractures of the distal ulna, occurring in Edinburgh adults, and presented according to the age and gender of those affected. (b) The distribution of the modes of injury involved in causing fractures of the distal ulna, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs).

The AO classification system¹⁴ describes isolated fractures of the distal ulna in the same grouping used for the distal radius (*i.e.* '23') with the additional suffixes A1.1 (fracture of the ulnar styloid process), A1.2 (simple fracture of the ulnar metaphysis) and A1.3 (comminuted fracture of the ulnar metaphysis). The distribution of fractures encountered in the present series, and classified according to this system, is shown in Table 3.32.

	Styloid (A1.1)	Metaphyseal (A1.2 & A1.3)	<i>p</i> -value
Fractures (n, %)	15 (44.1)	19 (55.9)	-
Gender ratio (M:F, %)	80:20	44:66	<i>p</i> =0.085*
Median age (yrs, IQR)	22 (20-42)	71 (44-83)	<i>p</i> <0.001**

Table 3.32 The number and frequency of fractures of the distal ulna, occurring in Edinburgh adults, according to the AO classification system. The age- and gender-related distribution of affected patients is also provided. *Chi square test. **MWU test.

3.9 Fractures of the carpus

The carpal bones, and their relationship with one another, allow a wide range of motion at the wrist. They are linked by a number of intrinsic and extrinsic ligaments. The most common *mechanism* of injury to the carpus (irrespective of the injury *mode*, or surrounding circumstances) involves a compressive force applied to the extended wrist joint¹⁷⁹. This commonly results from falling onto the outstretched hand. Other mechanisms include palmar flexion and twisting injuries. It has been suggested that the majority of carpal injuries and fractures represent sequential variants of perilunate dislocation^{179, 180}. The literature suggests that the majority of fractures within the carpus involve the scaphoid. Court-Brown and Caesar identified 159 carpal fractures in Edinburgh adults in 2000, representing 2.7% of all fractures¹³² and 82.4% of these injuries involved the scaphoid.

	Men (n=141)	Women (n=60)	Both (n=201)	p-value
Fractures (n)	144	61	205	-
Fracture incidence (n/10,000/yr, 95% CIs)	5.6 (4.7-6.6)	2.1 (1.6-2.7)	3.8 (3.3-4.3)	p<0.001*
Median age (yrs, IQR)	26 (21-37)	51 (28.5-63)	29 (22-46.5)	p<0.001**
Mode of injury (n, %)				
Simple fall	43 (29.9)	40 (65.6)	83 (40.5)	p<0.001*
Sports-related	46 (31.9)	8 (13.1)	54 (26.3)	
Direct blow	25 (17.4)	4 (6.6)	29 (14.1)	
Other	11 (7.6)	3 (4.9)	14 (6.8)	
RTA	11 (7.6)	2 (3.3)	13 (6.3)	
Fall down stairs	1 (0.7)	3 (4.9)	4 (2.0)	
Fall from a height	7 (4.9)	1 (1.6)	8 (3.9)	
Carpal bone (n, %)				
Scaphoid	100 (69.4)	42 (68.9)	142 (69.2)	p=0.04*
Lunate	2 (1.4)	0	2 (1.0)	
Triquetrum	18 (12.5)	13 (21.2)	31 (15.1)	
Pisiform	0	2 (3.3)	2 (1.0)	
Hamate	11 (7.6)	2 (3.3)	13 (6.3)	
Capitate	3 (2.1)	0	3 (1.5)	
Trapezoid	1 (0.7)	2 (3.3)	3 (1.5)	
Trapezium	5 (3.5)	0	5 (2.4)	
Combined fractures	4 (2.8)	0	4 (2.0)	

Table 3.33 The number, incidence and distribution of carpal fractures occurring in male and female adults in Edinburgh. The patient age distribution and modes of injury involved are also shown. *Chi square test. **MWU test; p-values have been calculated for comparisons between the genders. (RTA = road traffic accident).

In this cohort of adult fractures there were 205 carpal fractures, whose distribution is shown in Table 3.33, above. These injuries occurred in 201 patients, 71.6% of whom were men. One patient suffered two carpal fractures at presentation, occurring as part of a complex carpal fracture dislocation injury. Three patients sustained a recurrent scaphoid fracture (two

contralateral; one ipsilateral) within the study period. Carpal fractures accounted for 3.0% of all fractures and 4.9% of upper limb fractures. The median age of patients affected was 28 years (R 15-87 yrs, IQR 22-46 yrs). Significant gender-related differences were noted.

Men represented a younger cohort, commonly suffering injury as a result of sporting activity. Women were older and two-thirds sustained injury from a simple fall from a standing height. The overall incidence of carpal fractures was 3.8/10,000/yr (95% CI, 3.3-4.3), and Table 3.33 shows that the rate was significantly higher in men. The fracture distribution curves reflect the age- and gender-related differences (Fig. 3.36).

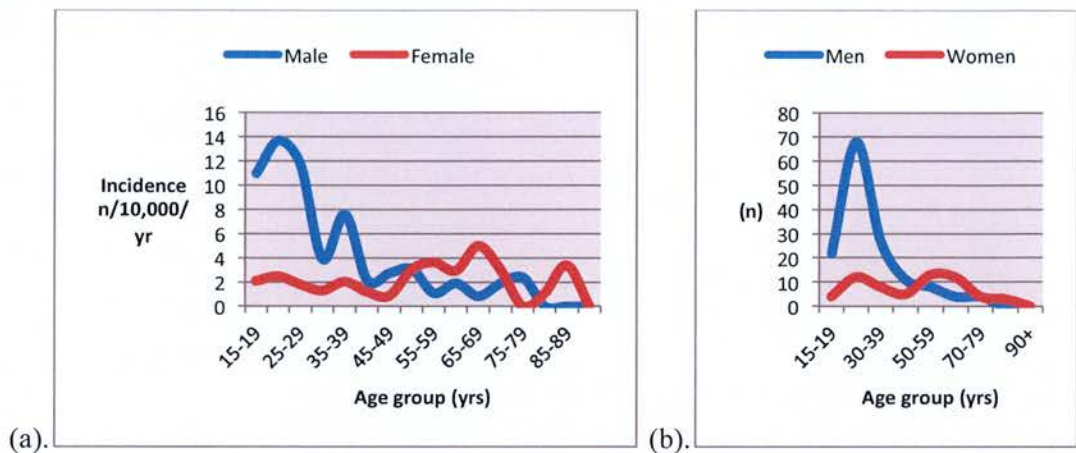


Figure 3.36 (a) The age- and gender-related *incidence* of carpal fractures occurring in Edinburgh adults. (b) The actual *number* of carpal fractures encountered, and presented according to patient age and gender.

A simple fall from a standing height, presumably onto the outstretched hand, was responsible for the majority of fractures in older adults. Sports-related activities caused a large proportion of injuries in young adults (Fig. 3.37, next page). The analysis of carpal fractures as a group is skewed by the high frequency of scaphoid fractures, and a separate analysis of these injuries is provided.

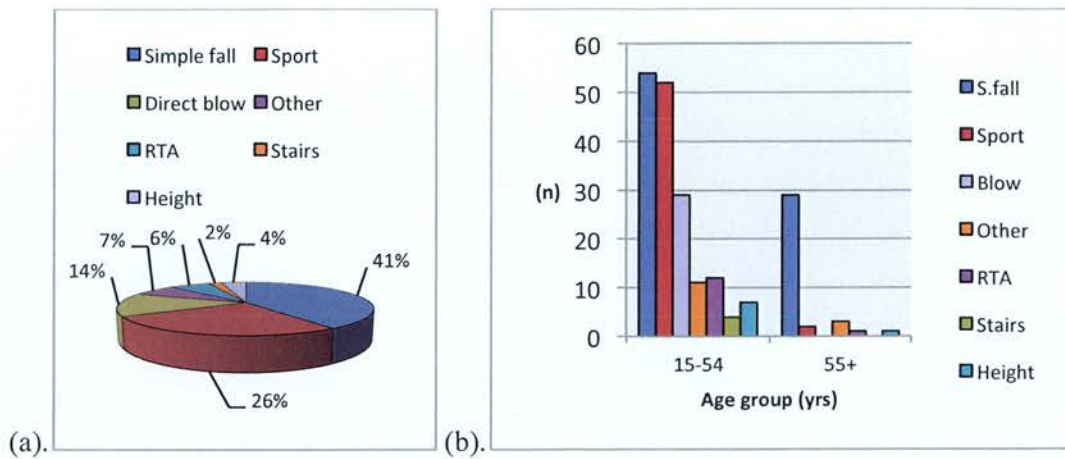


Figure 3.37 (a) The distribution of the modes of injury involved in causing carpal fractures in Edinburgh adults. (b) The distribution of injury modes presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from a height).

Scaphoid fractures

One hundred and forty five acute fractures of the scaphoid were recorded during the study period, representing 2.1% of all fractures. Three patients sustained a recurrent scaphoid fracture (two contralateral; one ipsilateral). There were no bilateral injuries, but one open fracture. The incidence was two to three times higher for scaphoid fractures than for non-scaphoid carpal fractures (Table 3.34). Sport accounted for one-third of injuries in this young, predominantly male population.

	Scaphoid #	Non-scaphoid #	p-value
Fractures (n, %)	145 (70.7)	60 (29.3)	-
Gender ratio (M:F, %)	71:29	68:32	$p=0.626^*$
Incidence (n/10,000/yr, 95% CI)	2.7 (2.2-3.1)	1.1 (0.8-1.4)	-
Median age (yrs, IQR)	27 (22-44.25)	34 (23-58)	$p=0.106^{**}$
Men	26 (20.5-36)	26.5 (22-39.75)	$p=0.317^{**}$
Women	42 (26.5-60)	58 (30-67)	$p=0.144^{**}$
Mode of injury (n, %)			
Simple fall	57 (39.0)	26 (44.1)	$p=0.032^*$
Sports-related	47 (32.2)	7 (11.9)	
Direct blow	16 (11.0)	13 (22.0)	
Other	8 (5.5)	6 (10.2)	
RTA	9 (6.2)	4 (6.8)	
Fall down stairs	4 (2.7)	0	
Fall from a height	5 (3.4)	3 (5.1)	

Table 3.34 The number, incidence and modes of injury involved with scaphoid and non-scaphoid carpal fractures in Edinburgh adults. The age- and gender-related distribution of affected patients is shown. *Chi square test. **MWU test. (*RTA* = road traffic accident).

Herbert and Fisher proposed a classification system for scaphoid fractures with the intention of identifying cases most suitable for operative fixation¹⁸¹. They described stable acute fractures (type A), unstable acute fractures (type B), delayed unions (type C) and established non-unions (type D). Other authors, including the AO Foundation¹⁴ prefer the classification system based upon the anatomic location of the fracture: distal one-third / tuberosity; waist; proximal pole. The distribution of scaphoid fractures identified in this study is shown in Table 3.35. Three fractures were sustained as part of a trans-scaphoid perilunate dislocation of the carpus, but the remaining 142 fractures represented isolated injuries.

	Distal third	Waist	Proximal pole	p-value
Fractures (n, %)	49 (34.5)	84 (59.2)	9 (6.3)	-
Gender ratio (M:F, %)	65:35	73:27	78:22	$p=0.593^*$
Median age (yrs, IQR)	30 (21.5-46)	27 (22-45)	25 (23-37.5)	$p=0.833^k$
Mode of injury (n, %)				
Simple fall	22 (44.9)	34 (40.5)	1 (11.1)	$p=0.078^*$
Sports-related	19 (38.8)	21 (25.0)	7 (77.8)	
Direct blow	6 (12.2)	10 (11.9)	0	
Other	1 (2.0)	5 (6.0)	0	
RTA	1 (2.0)	7 (8.3)	1 (11.1)	
Fall down stairs	0	4 (4.8)	0	
Fall from a height	0	3 (3.6)	0	

Table 3.35 The number and incidence of scaphoid fractures, occurring in Edinburgh adults, according to the anatomic location of the fracture. The age- and gender-related distribution of affected patients is also shown. *Chi square test. ^kKW test.

3.10 Fractures of the hand

Fractures and fracture dislocations involving the metacarpals and phalanges are some of the most frequently encountered orthopaedic injuries. The majority are closed, isolated injuries and a good functional result can be achieved if the complications of malunion and joint stiffness are avoided. Injuries involving multiple hand fractures, open fractures and those with associated nerve, tendon or blood vessel damage are more difficult to treat with the outcome being related to injury severity¹⁸².

A population based study from Canada reported a hand fracture incidence of 36/10,000/yr in children and adults¹⁸³. The data set used included ED data, but a large number of cases (72,481) were examined over a five-year period. The authors noted an increased incidence in patients aged 20 years or less, and the relative risk in men was twice that of women. Fractures of the metacarpals, phalanges and combination fractures accounted for 42%, 50% and 8% respectively, and the 5th ray was the most commonly involved. Stanton *et al* reported on 701 hand fractures in patients of all ages¹⁸⁴. Fractures most commonly affected patients aged ten to 15 years of age, and there was an overall male predominance (74%). The 5th ray accounted for 47% of injuries, and phalangeal fractures were slightly more common than those of the metacarpus (53:47 %). Ip *et al* reported a series of 924 hand fractures from 1984 to 1994 in Hong Kong¹⁸⁵. The main aim of the study was to report functional outcome following treatment rather than to describe patterns of fracture, and the incidence was not reported. The majority of fractures affected the phalanges (88%) with the proximal phalanx involved twice as often as the middle phalanx.

In this Edinburgh series, a total of 1,414 hand fractures affected 1,345 patients. Hand fractures accounted for 35.1% of upper limb fractures and 20.6% of all fractures. The frequency of open hand fractures was 7.0%. The median age of all patients was 30 years (R 15-100 yrs, IQR 21-45 yrs). The majority of affected patients were men (n=960, 71.4%) with a median age of 27 years (R 15-95 yrs, IQR 20-40 yrs). Female patients (n=385, 28.6%) had a median age of 42 years (R 15-100 yrs, IQR 25.5-60 yrs) and were significantly older than affected men ($p<0.001$, MWU test). The overall incidence was 25.9/10,000/yr (95% CI 24.6-27.3) and was significantly higher in men (39.1/10,000/yr, 95% CI 36.8-41.6) than in women (14.0/10,000/yr, 95% CI 12.6-15.4). The resultant fracture distribution curve is shown in Figure 3.38. It shows a unimodal young male pattern, with a smaller peak affecting older women, and should be considered a type A distribution¹³².

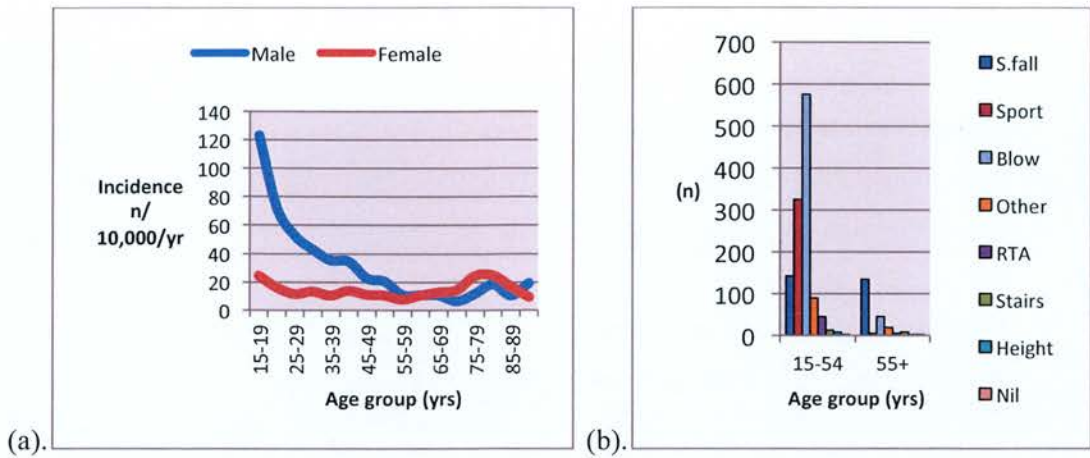


Figure 3.38 (a) The age- and gender-related incidence of hand fractures occurring in Edinburgh adults. (b) The distribution of the modes of injury involved in causing fractures of the hand, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

Figure 3.38 also shows the injury modes responsible for hand fractures. Younger adults aged 54 years or less accounted for 84.7% of hand fractures. Direct violence (punching injuries, other direct blows, crush and bite injuries) caused 43.8% of hand fractures, a larger proportion than in any other group of fractures. One-quarter of fractures occurred due to sporting activity and almost exclusively affected younger men. A similar pattern was reported by Stanton *et al*¹⁸⁴. The frequency of high energy fractures from RTAs or a falls from a height was low (4.2%).

For the purposes of analysis, multiple fractures in the hand were defined as a ‘combination’ injury. The distribution of hand fractures is shown in Table 3.36 (next page). Isolated metacarpal fractures were seen in a predominantly young male population, the majority of fractures were caused by a direct blow, and the frequency of open injuries and fracture dislocations was low. Isolated phalangeal fractures occurred in a slightly older patient group, although the majority of those affected were young men. One-third of phalanx fractures were caused by sporting activity. The frequency of open injuries and associated dislocations was higher. Combination fractures had a lower frequency of open injury and dislocation, but it must be stressed that more severe hand trauma was treated elsewhere and is not presented here.

	Metacarpus	Phalanges	Combination	p-value
Fractures (n, %)	618 (43.7)	636 (45.0)	160 (11.3)	-
Gender ratio (M:F, %)	79:21	65:35	70:30	$p < 0.001^*$
Incidence (n/10,000/yr, 95% CIs)	11.3 (10.5-11.3)	11.7 (10.8-12.6)	2.9 (2.5-3.4)	-
Median age (yrs, IQR)	25 (20-38)	36 (23-50)	31.5 (21-53)	$p < 0.001^k$
Men	24 (19-33)	33 (21-44.5)	28 (18-41)	
Women	36 (23-67)	43 (28-59)	66 (31-78.5)	
Mode of injury (n, %)				$p < 0.001^*$
Simple fall	112 (18.1)	131 (20.6)	32 (20.0)	
Sports-related	104 (16.8)	190 (29.9)	35 (21.9)	
Direct blow	342 (55.3)	213 (33.5)	65 (40.6)	
Other	28 (4.5)	66 (10.4)	13 (8.1)	
RTA	17 (2.8)	24 (3.8)	8 (5.0)	
Fall down stairs	10 (1.6)	6 (0.9)	5 (3.1)	
Fall from a height	5 (0.8)	3 (0.5)	2 (1.3)	
Nil	0	3 (0.5)	0	
Open injuries (n, %)	4 (0.6)	13.5	5.6	$p < 0.001^*$
Dislocations (n, %)	6 (1.0)	6.1	1.3	$p < 0.001^*$

Table 3.36 The number, incidence and causative modes of injury for fractures of the hand occurring in Edinburgh adults. The age- and gender-related distribution of those affected is given, in addition to the frequency of open injuries and fracture dislocations. *Chi square test. ^kKW test. (RTA = road traffic accident).

Metacarpals

Isolated fractures of the metacarpals are described anatomically as those affecting the head or neck, the shaft and the base. The AO classification further divides head and base fractures into extra-articular (type A), partial articular (type B) and complete articular (type C) fractures. A partial articular fracture dislocation of the base of the first metacarpal was first recognised in the nineteenth century by Bennett, and still bears his name¹⁸⁶. The complete articular variant was described in 1910 by Rolando¹⁸⁷.

Injury to the 5th ray was commonest, with the shaft being involved in half of cases (Table 3.37, next page). A direct blow caused 50.0% of 5th metacarpal base fractures, 68.1% of shaft fractures and 77.4% of head or neck fractures. This pattern has led to the term ‘boxer’s’ fracture, which is used to describe fracture of the 5th metacarpal neck sustained by throwing a punch¹⁸⁸. A similar pattern of fracture was observed affecting the 4th and 2nd rays. Although the proportion of 2nd ray neck fractures was greater, a direct blow remained the predominant injury mode. Fractures of the 3rd and 1st metacarpals commonly resulted from sporting activity. Fractures of the 1st ray occurred almost exclusively at the base, with half of these injuries involving the articular surface. The vast majority of metacarpal fractures were closed injuries. Four open fractures were seen: three affecting the 5th ray (two direct blows,

one simple fall) and one affecting the 1st metacarpal base (sustained by a butcher chopping meat).

	1 st ray	2 nd ray	3 rd ray	4 th ray	5 th ray
Fractures (n, %)	57 (9.2)	37 (6.0)	39 (6.3)	98 (15.9)	387 (62.6)
Gender ratio (M:F, %)	90:10	78:22	72:28	77:23	79:21
Mode of injury (n, %)					
Simple fall	11 (19.3)	3 (8.1)	7 (17.9)	16 (16.3)	75 (19.4)
Sports-related	18 (31.6)	10 (27.0)	16 (41.0)	21 (21.4)	39 (10.1)
Direct blow	11 (19.3)	20 (54.1)	10 (25.6)	51 (52.0)	250 (64.6)
Dislocations (n, %)	2 (3.5)	0	0	2 (2.0)	2 (0.5)
Open injuries (n, %)	1 (1.8)	0	0	0	3 (0.8)
Head / neck (n, %)	3 (5.3)	22 (59.5)	11 (28.2)	15 (15.3)	120 (31.0)
A	3	16	8	14	110
B	0	4	3	1	6
C	0	2	0	0	4
Shaft (n, %)	1 (1.8)	12 (32.4)	25 (64.1)	72 (73.5)	191 (49.4)
spiral / oblique	0	8	17	45	73
transverse	2	4	2	25	109
wedge / comminuted	0	0	6	2	9
Base (n, %)	53 (93.0)	3 (8.1)	3 (7.7)	11 (11.2)	76 (19.6)
A	28	1	3	2	35
B	23	1	0	9	29
C	2	1	0	0	12

Table 3.37 The number and incidence of isolated metacarpal fractures, occurring in Edinburgh adults, and presented according to their distribution across the five rays of the hand. The frequency of associated open injuries and dislocations is shown. The anatomic fracture location, in terms of head and neck, shaft, or basal fractures is also given.

A significant difference between the genders was noted with regard to the mode of injury responsible. Female patients accounted for 51% of simple fall fractures and 40% of injuries sustained from falling down stairs, but only 11% of direct blow fractures ($p < 0.001$, Chi square test).

Finger phalanges

Isolated fractures of the proximal (P1), middle (P2) and distal (P3) phalanges of the fingers and proximal (T1) and distal (T2) phalanges of the thumb numbered 636. They represented 45.0% of hand fractures and 15.3% of upper limb fractures. The little finger was most commonly affected, followed by the thumb, ring, middle and index fingers (Table 3.38, next page). Fractures towards the ulnar side of the hand occurred in an older patient age group ($p = 0.027$, KW test), with a trend towards increased female involvement ($p = ns$, Chi square test). No significant difference was found between the rays with regards to the mode of injury involved.

	Thumb	Index	Middle	Ring	Little
Fractures (n, %)	138 (21.7)	84 (13.2)	97 (15.3)	111 (17.4)	206 (32.4)
Gender ratio (M:F, %)	66:34	74:26	66:34	60:40	61:39
Median age (yrs, IQR)	33 (22-48)	29 (20-45)	37 (21-47.5)	38 (26-52)	37 (25-54)
Mode of injury (n, %)					
Simple fall	24 (17.4)	11 (13.1)	15 (15.5)	24 (21.6)	57 (27.7)
Sports-related	47 (34.1)	32 (38.1)	29 (29.9)	26 (23.4)	56 (27.2)
Direct blow	41 (29.7)	26 (31.0)	40 (41.2)	46 (41.4)	60 (29.1)
Dislocations (n, %)	7 (5.1)	2 (2.4)	5 (5.2)	5 (4.5)	20 (9.7)
Open injuries (n, %)	21 (15.2)	14 (16.7)	18 (18.6)	13 (11.7)	20 (9.7)

Table 3.38 The number and incidence of isolated finger phalangeal fractures, occurring in Edinburgh adults, and presented according to their distribution across the five digits of the hand. The frequency of associated open injuries and dislocations is shown, as well as the three most common causative modes of injury.

Table 3.39 and Figure 3.39 give further details about the distribution of fractures within each ray. Fracture of P2 of the fingers was universally uncommon, as was fracture at the base of the P1. The exception was the thumb where one-quarter of injuries involved the metacarpophalangeal (MCPJ) articulation. Tuft fractures and open injuries were both more common on the radial side of the hand.

Location (n, %)	Thumb*	Index	Middle	Ring	Little*	All*
T3 / P3 fractures	45 (32.6)	20 (23.8)	20 (20.6)	23 (20.7)	15 (7.3)	
tuft / shaft	34	17	20	18	9	123 (19.3)
extra-articular base	11	3	0	5	6	
DIPJ / Thumb IPJ	38 (27.5)	13 (15.5)	17 (17.5)	35 (31.5)	28 (13.6)	
distal joint surface	34	13	17	29	27	131 (20.6)
proximal joint surface	4	0	0	6	1	
P2 fractures		3 (3.6)	3 (3.1)	6 (5.4)	6 (2.9)	
neck	-	0	0	1	2	
shaft	-	1	3	3	3	18 (2.8)
extra-articular base	-	2	0	2	1	
PIPJ		16 (19.0)	34 (35.1)	25 (22.5)	56 (27.2)	
distal joint surface	-	16	34	25	45	131 (20.6)
proximal joint surface	-	0	0	0	11	
T1 / P1 fractures	22 (15.9)	22 (26.2)	12 (12.4)	19 (17.1)	89 (43.2)	
neck	0	1	2	1	3	
shaft	6	15	6	7	31	164 (25.8)
extra-articular base	16	6	4	11	55	
MCPJ		10 (11.9)	11 (11.3)	3 (2.7)	10 (4.9)	
distal joint surface	32 (23.2)	10 (11.9)	11 (11.3)	3 (2.7)	10 (4.9)	66 (10.4)
Total	138 (100)	84 (100)	97 (100)	111 (100)	206 (100)	636 (100)

Table 3.39 The number and distribution of isolated finger fractures with relation to the phalanx or joint involved. DIPJ = distal interphalangeal joint. PIPJ = proximal interphalangeal joint. *One thumb and two little finger fractures could not be further classified due to missing radiographs.

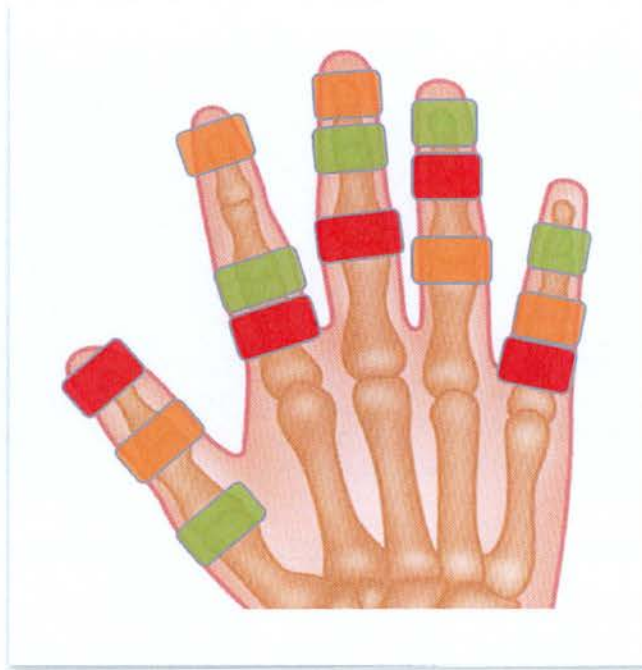


Figure 3.39 A diagrammatic representation of the anatomical distribution of finger phalangeal fractures, occurring in Edinburgh adults. The three commonest sites of involvement within each ray are depicted by the *red* (most frequent), *amber* (second most frequent), and *green* (third most frequent) shaded areas.

The patterns of finger fracture from the present series are similar to those reported by Ip and colleagues from Hong Kong¹⁸⁵. They too reported that P1 fractures outnumbered those of P2, although they noted a higher total number of P2 fractures in their series. The distribution of fractures within P1 was the same for both series, although no mention is made of intra-articular involvement. These results also bear similarities to those of Stanton *et al*¹⁸⁴. They noted that P3 involvement was more common than P1 injury, with P2 injury being least common.

Combination hand fractures

One hundred and sixty fractures of the hand involving two or more bones were recorded during the study period, accounting for 11.3% of hand fractures. This is similar to the frequency of 8% reported by the Canadian group¹⁸³, although it is likely to be a conservative estimate in the Edinburgh population (with a proportion of combination hand fractures and the majority of severe hand trauma dealt with by the plastic surgical services). Combination fractures occurred in 98 patients, 70% of whom were men. Male patients (median age 28 years, IQR 18-41 yrs) were significantly younger than women (median age 66 years, IQR 31-78.5 yrs) in this group ($p < 0.001$, MWU test). The resultant distribution curve produced by

analysing *each episode* rather than *each fracture* is shown in Figure 3.40, and confirms a unimodal older female incidence and bimodal male incidence (type G). The second peak in men is small. The predominant mode of injury in older adults was a simple fall, while younger adults suffered more high energy injuries ($p < 0.001$, Chi square test).

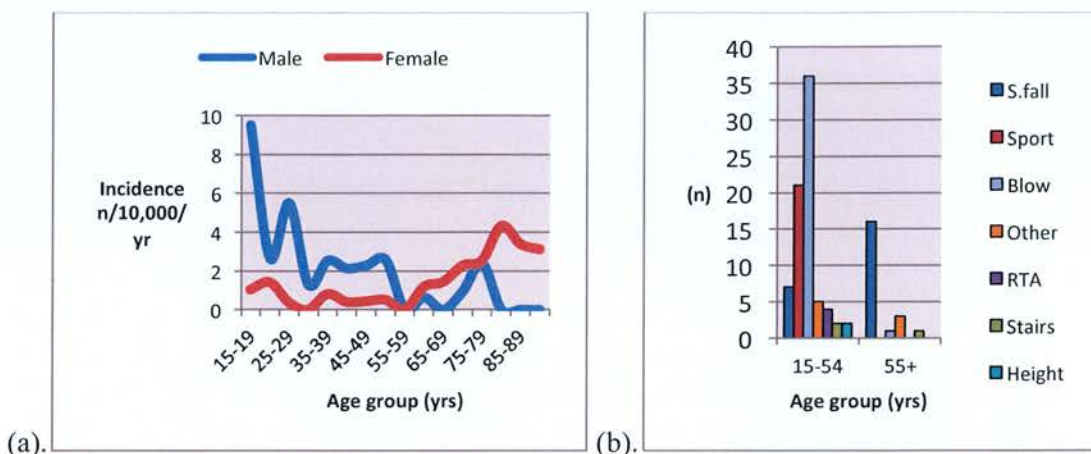


Figure 3.40 (a) The age- and gender-related incidence of combination hand fracture episodes occurring in Edinburgh adults. (b) The distribution of the modes of injury involved in causing combination fractures of the hand, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

	Multiple phalanges	Multiple metacarpals	Metacarpal and phalanx	p-value
Fractures (n, %)	29 (30.0)	59 (60.2)	10 (10.2)	-
Gender ratio (M:F, %)	45:55	83:17	70:30	$p < 0.001^*$
Median age (yrs, IQR)	42 (25.5-74)	29 (18-46)	23.5 (20-51)	$p = 0.031^k$
Mode of injury (n, %)				$p = 0.002^*$
Simple fall	11 (37.9)	10 (16.9)	2 (20.0)	
Sports-related	7 (24.1)	8 (13.6)	6 (60.0)	
Direct blow	4 (13.8)	32 (54.2)	1 (10.0)	
Open injuries (n, %)	4 (13.8)	2 (3.4)	1 (10)	$p = 0.191^*$

Table 3.40 The number and incidence of combination hand fractures occurring in Edinburgh adults. The age- and gender-related distribution of affected patients is given, as well as the three most common injury modes involved. *Chi square test. ^kKW test.

The most common subgroup involved two or more fractures of the metacarpals. These injuries occurred in young men as the result of a direct blow (Table 3.40, above). Multiple finger fractures occurred in the only group of patients with a greater proportion of women affected. Many older women had suffering injury by low energy means. Fractures affecting the metacarpus and phalanges made up the smallest group of hand fractures, and many resulted from sports-related injuries.

3.11 Fractures of the proximal femur

Fractures of the proximal femur include hip fractures and a smaller number of isolated trochanter femoral head fractures. The present series included 821 proximal femoral fractures sustained by 809 patients, giving an overall incidence of 15.1/10,000/yr (95% CI, 14.1-16.1). They accounted for 11.9% of all fractures, and were the commonest subtype seen in the lower limb (32.0%). Twelve patients (nine women, three men) suffered a recurrent injury. Nine patients fractured the contralateral hip, two patients sustained a greater trochanter fracture followed by a hip fracture, and one elderly woman suffered a recurrent fall onto the ipsilateral hip, sustaining a greater trochanter fracture (around a hemiarthroplasty implant). Women were more commonly affected than men (Table 3.41).

	Men (n=220)	Women (n=589)	Both (n=809)	p-value
Fractures (n, %)	223 (27.2)	598 (72.8)	821 (100)	-
Fracture incidence (n/10,000/yr, 95% CIs)	8.6 (7.5-9.8)	20.9 (19.3-22.7)	15.1 (14.1-16.1)	p<0.001*
Median age (yrs, IQR)	80 (71-86)	83 (78-88)	83 (76-88)	p<0.001**
Mode of injury (n, %)				
Simple fall	190 (85.2)	551 (92.1)	741 (90.3)	p<0.001*
Sports-related	1 (0.4)	1 (0.2)	2 (0.2)	
Direct blow	0	2 (0.3)	2 (0.2)	
Other	13 (5.8)	18 (3.0)	31 (3.8)	
RTA	7 (3.1)	1 (0.2)	8 (1.0)	
Fall down stairs	6 (2.7)	13 (2.2)	19 (2.3)	
Fall from a height	4 (1.8)	0	4 (0.5)	
Nil	2 (0.9)	12 (2.0)	14 (1.7)	
Intracapsular (Neck)	122 (54.7)	304 (50.9)	426 (51.9)	p=0.730*
displaced	96 (43.0)	230 (38.5)	326 (39.7)	
undisplaced	26 (11.7)	74 (12.4)	100 (12.2)	
Extracapsular (Trochanteric & Basal)	92 (41.3)	275 (46.0)	367 (44.7)	
Isolated trochanters	7 (3.1)	14 (2.3)	21 (2.6)	
Head fracture	2 (0.8)	0	2 (0.2)	
No films available	1 (0.4)	4 (0.7)	5 (0.6)	

Table 3.41 The number and incidence of fractures of the proximal femur, occurring in male and female patients, and distributed according to anatomical fracture location. The distribution of patient age is also shown. *Chi square test. **MWU test. p-values have been calculated for comparisons between the genders. (RTA = road traffic accident).

The median age of all patients was 83 years (R 35-102 yrs, IQR 76-88 yrs), with women representing a slightly older age group. The incidence was low in young men and women but increased with advancing age. In men, the incidence began to rise exponentially after the age of 75 years, and peaked at 308.9/10,000/yr in those aged 90 years or more. The rise in female incidence occurred earlier (at 60 years) but did not rise exponentially until beyond 75

years of age. The peak incidence in women was 375.9/10,000/yr. The resultant fracture distribution curve (Fig. 3.41) illustrates the unimodal nature of proximal femoral fracture incidence in both genders, and is a type F curve¹³².

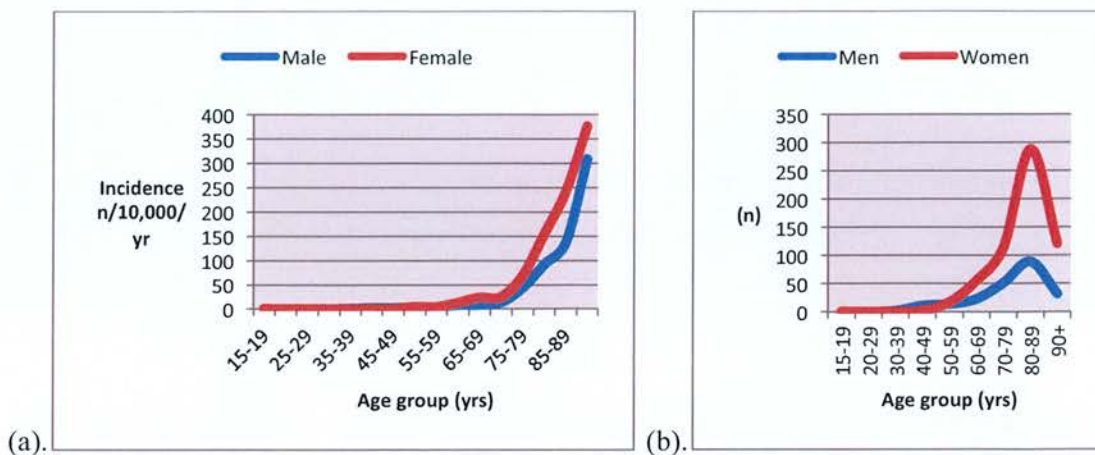


Figure 3.41 (a) The age- and gender-related *incidence* of proximal femoral fractures occurring in Edinburgh adults. (b) The actual *number* of proximal femoral fractures encountered, and presented according to patient age and gender.

The exponential rise in older women has been reported in prior studies. In rural Norway, the pattern was even more pronounced, rising from 21/10,000/yr (65-69 yrs) to 497/10,000/yr (95+ yrs)¹⁸⁹. The authors also reported substantial seasonal variation, with higher fracture incidence during the winter months. This pattern has also been reported in Spain and the United States^{190, 191}, and has been replicated in this study (Fig. 3.42).

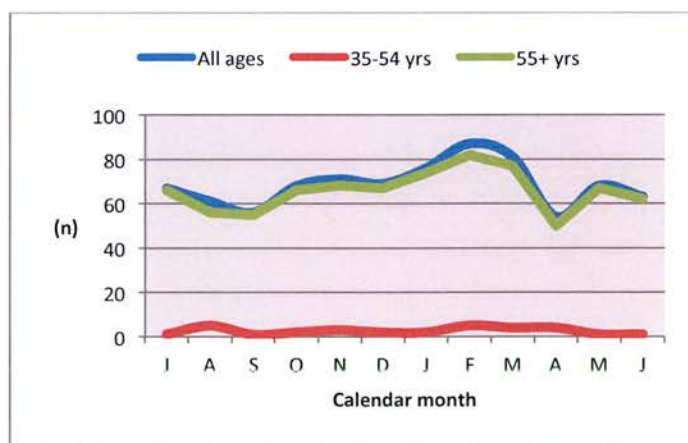


Figure 3.42 The seasonal and age-related distribution of fractures of the proximal femur, occurring in Edinburgh adults. The total number of fractures is shown, as well as the number affecting younger and older adults.

Robinson *et al* reported that proximal femoral fractures in young adults represent a very different injury group when compared to the insufficiency fractures resulting from a simple fall in the elderly¹⁹². The authors reported a greater proportion of fractures resulting from high energy trauma, and the subtrochanteric and vertically oriented femoral neck fractures were more common. In the present series, 31 fractures (3.8%) occurred in patients aged younger than 55 years of age (Fig. 3.43). This group contained a significantly greater proportion of male patients (65.5%), than the older patient group (25.7%), ($p < 0.001$, Chi square test). The frequency of fracture resulting from RTAs or falls from a height was also greater (25.9% vs. 0.6%), ($p < 0.001$, Chi square test). In the older patient group, the majority of fractures were sustained by low energy trauma. A small number of injuries ($n = 14$, 1.8%) represented pathological fractures through bone weakened by tumour.

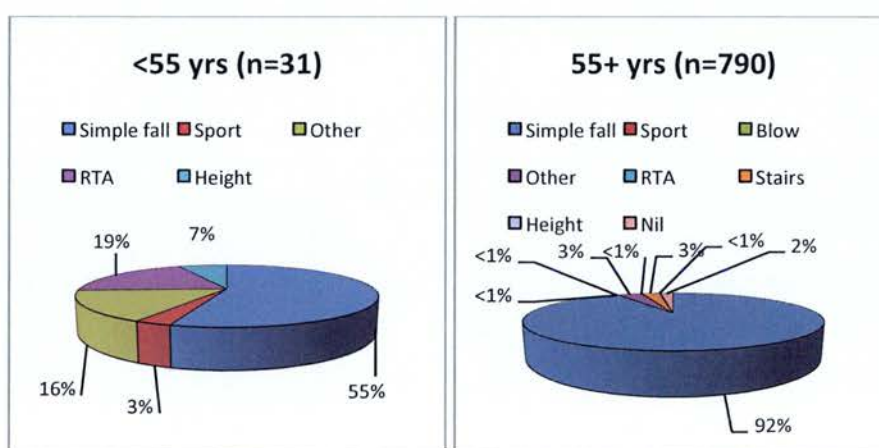


Figure 3.43 The frequency of the different modes of injury responsible for causing proximal femoral fractures in Edinburgh adults, and presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

A number of classification systems have been devised for proximal femoral fractures, and in particular for hip fractures. The Garden classification for fractures of the femoral neck was described in 1961⁵⁸ and is based on the degree of fracture displacement on the antero-posterior radiograph. Groups 1 and 2 describe minimally and undisplaced subcapital fractures, respectively. Group 3 describes displaced fractures where the femoral head has not lost contact with the neck. Group 4 is reserved for completely displaced injuries. The Garden classification has been widely used due to its relative simplicity, and is the most frequently quoted system in the orthopaedic literature pertaining to femoral neck fractures¹⁹³.

Pauwels' classification of femoral neck fractures is based on the plane of the fracture¹⁹⁴. He based fracture types 1, 2 and 3 on whether the predominant plane of the fracture was transverse, oblique or vertical, respectively. This classification has not been shown to reliably describe the fracture, or predict outcome¹⁹⁵.

Evans described a post-treatment classification of intertrochanteric fractures, aimed at describing the overall stability of the fracture configuration after surgery¹⁹⁶. Jensen modified this system slightly¹⁹⁷. Both systems describe the presence of medial and / or posterolateral comminution contributing to the inherent instability of certain trochanteric fracture subtypes.

The modified AO classification system, used by the OTA¹⁴, attempts to comprehensively classify proximal femoral fractures, and draws upon many of the elements described in the previous classification systems. However, it fails to classify isolated fractures of the greater or lesser trochanters. Intertrochanteric, femoral neck and femoral head fractures are respectively referred to as types 31-A, 31-B and 31-C. Further subclassification has not been shown to be reliable for femoral neck¹⁹⁸ or intertrochanteric¹⁹⁹ fractures. However, the literature does suggest that the OTA classification shows good reliability (kappa coefficient 0.6-0.8) when used to describe the following broad categories:

- 31-A1 – intertrochanteric, stable.
- 31-A2 – intertrochanteric, unstable.
- 31-A3 – trans-trochanteric (including transverse and reverse oblique injuries).
- 31-B1 – femoral neck, minimally displaced.
- 31-B2.1 – femoral neck, basicervical.
- 31-B2.2, 31-B2.3, 31-B3 – femoral neck, displaced.

Importantly, for the purposes of this study hip fractures were defined as those occurring in the femoral neck, trochanteric and intertrochanteric regions. Fractures of the subtrochanteric region have been presented and dealt with alongside femoral diaphyseal fractures in the next section (3.12). The AO system, detailed above, treats trochanteric (31-A) and neck (31-B) fractures as separate from those occurring in the subtrochanteric region of the femoral diaphysis (32-A, B and C). For this reason, the analysis of hip fractures presented here does not include subtrochanteric fractures.

	Intertrochanteric (n=367)				Femoral neck (n=426)		p-value
	Stable	Unstable	Transverse	Basicervical	Undisplaced	Displaced	
Fractures (n)	108	129	47	83	100	326	-
Gender ratio (M:F, %)	29:71	19:81	30:70	27:73	26:74	29:71	p=0.392*
Median age (yrs, IQR)	84 (76-90)	83 (77-88)	83 (75-91)	85 (80-88)	79 (73-85)	83 (76-87)	p=0.001 ^k
Men	80 (71-90)	79 (70-84)	80 (63-91)	83 (79-87)	77.5 (70-83)	81 (74-86)	p=0.356 ^k
Women	84 (79-90)	85 (79-90)	84 (76-91)	85 (80-88)	79.5 (74-86)	83 (77-88)	p=0.003 ^k
Mode (n, %)							
Simple fall	95 (88.0)	123 (95.3)	41 (87.2)	71 (85.5)	87 (87.0)	305 (93.6)	p=0.038*
RTA/Height	4 (3.8)	1 (0.8)	1 (2.1)	0	1 (1.0)	3 (0.9)	
Nil	0	2 (1.6)	1 (2.1)	1 (1.2)	3 (3.0)	5 (1.5)	
% <55 yrs	4.6	2.3	6.4	0	7.0	3.1	p=0.116*

Table 3.42 The distribution of (extracapsular) intertrochanteric and (intracapsular) femoral neck fractures occurring in Edinburgh adults (n=793). Fractures are arranged in terms of stability and displacement as described by the AO classification system. The age- and gender-related distribution of affected patients is given, as well as the proportion of injuries that occurred following a simple fall, high energy trauma, or as pathological fractures. *Chi square test. ^kKW test. (*RTA* = road traffic accident; *Height* = fall from a height).

Most hip fracture studies report an approximately equal split in terms of the proportion of extracapsular and intracapsular fractures reported. The present study found intracapsular fractures of the femoral neck to account for 53.7% of hip fractures (Table 3.42, above). Minimally displaced injuries affected a younger patient group, with 7.0% occurring in patients aged less than 55 years. Extra-capsular hip fractures, including basicervical injuries, accounted for 46.3%. The unstable fracture types occurred more often in elderly women, predominantly resulting from a simple fall from a standing height (95.3%). The frequency of intertrochanteric fractures has not changed when compared to the Edinburgh population in 2000¹³². In Norway, Finsen and colleagues reported an increase in the proportion of intertrochanteric fractures, from 32% in 1972 to 68% in 1998²⁰⁰.

Twenty one (2.6%) patients with a median age of 82 years (R 41-98 yrs, IQR 64.5-85 yrs) sustained an isolated fracture of the greater trochanter. There were no isolated lesser trochanter injuries. Seven male patients were affected, and represented a significantly younger group (median age 60 years, IQR 54-79 yrs) when compared to affected female patients (median 83 years, IQR 80-85 yrs), (p=0.014, MWU test). All fractures resulted from low energy trauma. Three fractures were periprosthetic in nature, involving a fracture of the trochanter in the presence of a femoral hemiarthroplasty component.

Femoral head fractures occur in association with hip dislocation. Isolated fractures in the absence of hip dislocation have been reported, but are extremely rare^{201, 202}. The

classification system used to describe posterior hip dislocations was proposed by Thompson and Epstein²⁰³. Pipkin further divided femoral head fracture dislocations into those with a fracture situated caudad (type 1) or cephalad (type 2) to the fovea centralis, those with an associated femoral neck fracture (type 3), and those with an accompanying acetabular fracture (type 4)²⁰⁴. Only two such injuries occurred in the present series. Both femoral head fractures occurred in restrained male drivers involved in RTAs. One patient suffered a Pipkin 4 injury. The second patient sustained a Pipkin 2 femoral head fracture, a lateral compression pelvic ring fracture, a contralateral femoral shaft fracture, and an open injury involving the ipsilateral tibial shaft and plateau.

Associated fractures were seen in 46 (5.7%) of the 809 patients sustaining proximal femoral fractures, including the two cases described above (Table 3.43). Men represented a younger patient group, with a greater proportion of injuries resulting from high energy trauma. The distribution of proximal femoral fracture type was no different between groups ($p=0.256$, Chi square test). The commonest associated fracture types were those of the proximal humerus and distal radius, occurring most often in elderly women.

	Men	Women	p-value
Fractures (n, %)	14 (30.4)	32 (69.6)	-
Median age (yrs, IQR)	68 (49-80.5)	79 (75-88)	$p=0.007^{**}$
Mode of injury (n, %)			
Simple fall	8 (57.1)	31 (96.9)	$p=0.001^*$
RTA / Height	6 (42.8)	0	
% <55 years	5 (35.7)	0	$p=0.001^*$
Commonest associated fracture types (%)	Femoral shaft (18%) Prox. Humerus (14%)	Prox. Humerus (47%) Distal radius (38%)	-

Table 3.43 The age- and gender-related distribution of patients suffering a fracture of the proximal femur who presented with associated fractures during the same injury episode. The two most common associated fracture types are given, as well as the proportion of patients injured as a result of a simple fall or high energy trauma. *Chi square test. **MWU test. (RTA = road traffic accident; Height = fall from a height).

3.12 Subtrochanteric and femoral shaft fractures

Femoral shaft fractures include those of the subtrochanteric region, as well as fractures of the diaphysis proper. The combination of an aging population and an increased use of femoral implants (as part of hip and knee arthroplasty, hip hemiarthroplasty, and fracture fixation) has led to the emergence of a subgroup of periprosthetic femoral shaft fractures.

Fractures of the femoral shaft have long been associated with young adults and high energy trauma. Arneson *et al* reported on femoral shaft fractures over a twenty year period in Minnesota²⁰⁵, and described 54 (13.4%) in the subtrochanteric region, 210 (52.2%) in the diaphysis and 123 (30.6%) involving the distal femur. Fifty eight percent were due to ‘severe trauma’, occurring especially in younger men and commonly involving the diaphysis. Further attention was brought to the subject of high energy femoral diaphyseal fractures when Bone *et al*²⁰⁶ published their important work demonstrating the reduction in morbidity and mortality following early operative stabilisation of these injuries in adults aged 65 years or less. Wolinsky presented a series of 515 femoral shaft fractures, all resulting from high energy trauma (RTAs 91%; falls from a height 3%; gunshot wounds 2%) and reported that 70% occurred in men, with an average age of 27 years²⁰⁷.

Salminen described 201 injuries in a Finnish population, and noted that a large proportion (75%) resulted from high energy trauma, mostly RTAs²⁰⁸. The authors also stated the ‘unexpected’ presence of 50 low energy fractures; commonly spiral fractures of the mid-diaphysis in osteoporotic bone²⁰⁹. The Minnesota study also reported that one-third of their fractures were associated with ‘moderate trauma’, commonly seen in older women and associated with evidence of osteopenia²⁰⁵. A careful review of the early fracture epidemiology work of Buhr and Cooke⁸⁴ and Knoweldon⁸⁵ reveals that the authors recognised the bimodal distribution of these injuries in the 1950s.

Author	Year	Country	Incidence (n/10,000/yr)		
			Male	Female	Overall
Arneson ²⁰⁵	1965-84	USA	-	-	3.7
Current	2007-08	UK	1.6	1.9	1.8
Bengner ²¹⁰	1973-83	Sweden	0.9*	1.2*	1.1*
Salminen ²⁰⁸	1990s	Finland	-	-	1.0
Court-Brown ¹³²	2000	UK	-	-	1.0

Table 3.44 Studies reporting the incidence of femoral shaft fracture in adults. *The figures have been indirectly calculated from the authors’ results, and are approximate.

Ninety six femoral shaft fractures occurred in 96 patients, with a median age of 75.5 years (IQR 59.5-85 yrs). The incidence was 1.8/10,000/yr (95% CI 1.4-2.1) which represents an 80% increase compared to the incidence recorded in Edinburgh adults in 2000¹³² (Table 3.44, previous page). There were 54 female patients (56.3%) with a median age of 80.5 years (IQR, 72-87 yrs). The median age of affected male patients (n=42, 53.7%) was 64.5 years (IQR, 43.5-77yrs). A comparative analysis of the subtrochanteric, diaphyseal and periprosthetic groups is shown in Table 3.45. The overall distribution of AO type A (85.4%), type B (12.5%) and type C (2.1%) injuries shown here differs significantly from the pattern reported in the Finnish study²⁰⁸ (48%, 39% and 13%, respectively). Similarly, the rate of open fractures was lower in this series (5.2% vs. 12.4%).

	Subtrochanteric	Diaphyseal	Periprosthetic	p-value
Fractures (n, %)	25 (26.0)	40 (41.7)	31 (32.3)	-
Gender ratio (M:F, %)	40:60	48:52	42:58	p=0.813*
Median age (yrs, IQR)	76 (62-83.5)	68.5 (47-81.5)	80 (71-87)	
Men	62 (40-77)	51 (25-68)	76 (63-84.5)	p=0.045 ^k
Women	82 (72-88)	78 (65-89.5)	84.5 (74-87)	
Mode of injury (n, %)				
Simple fall	17 (68.0)	16 (40.0)	28 (90.3)	
Sports-related	0	0	1 (3.2)	
Direct blow	0	3 (7.5)	0	p=0.004*
Other	0	2 (5.0)	0	
RTA	1 (4.0)	8 (20.0)	0	
Fall down stairs	0	2 (5.0)	1 (3.2)	
Fall from a height	3 (12.0)	5 (12.5)	0	
Nil	4 (16.0)	4 (10.0)	1 (3.2)	
Fracture pattern (n, %)				
Type A (simple)	20 (80.0)	35 (87.5)	27 (87.1)	p=0.793*
Type B (wedge)	4 (16.0)	4 (10.0)	4 (12.9)	
Type C (complex)	1 (4.0)	1 (2.5)	0	
% open fractures	0	12.5	0	-

Table 3.45 The number and frequency of fractures of the femoral shaft, occurring in Edinburgh adults, according to their anatomical location and proximity to an orthopaedic implant. The age- and gender-related distribution of those affected is shown, as well as the modes of injury involved. The fracture pattern, according to the AO classification system¹⁴, and the frequency of open fractures, are also given. *Chi square test. ^kKW test. (RTA = road traffic accident).

Subtrochanteric femoral fractures

The subtrochanteric region of the femur is one of the most highly stressed areas in the skeleton, and fractures of the femoral shaft at this level (by definition within 5cm of the inferior aspect of the lesser trochanter^{211, 212}) pose a difficult management problem.

Subtrochanteric fractures tend to occur in two distinct patient groups: the young adult

suffering high energy injury, and the older patient sustaining a low energy fracture through osteoporotic bone²¹³.

Various classification systems can be used for subtrochanteric fractures, but none has been shown to be particularly reliable or reproducible²¹². The Russell-Taylor system divides fractures into type 1 or 2 depending on the integrity of the proximal fragment, in particular the piriform fossa²¹⁴. The suffix A or B denotes 'no involvement' or 'involvement' of the lesser trochanter, respectively. The Seinsheimer classification is more detailed, and attempts to grade fracture obliquity and the degree of comminution²¹⁵. The AO classification describes the obliquity and degree of comminution in the subtrochanteric region. Some authors have chosen to include 31-A3 trans-trochanteric fractures as true subtrochanteric injuries²¹¹. However, for the purposes of this analysis, only AO subtypes 32-A1.1, A2.1, A3.1, B1.1, B2.1 and B3.1 have been included (see the Appendix).

Twenty five patients suffered a subtrochanteric femoral fracture (Table 3.50), accounting for 26.0% of femoral shaft fractures. This proportion has remained essentially unchanged from that seen in 2000 (30%)¹³² and therefore the incidence of these injuries (0.5/10,000/yr, 95% CI 0.3-0.7) has increased in tandem with femoral shaft fractures overall. The median age of patients was 76 years (IQR, 62-83.5 yrs) with a range from 29 to 96 years. Male patients represented a significantly younger group than female patients ($p=0.006$, MWU test). The resultant type F fracture distribution curve (Fig.3.44, next page) shows an age-related increase in incidence that affects both genders, but is more pronounced in women. Analysis of the mode of injury involved reveals a distinct age-related difference. In older adults, they were caused by low energy simple falls from a standing height and a small number of pathological events. In younger patients, high energy injury modes (and one pathological fracture case) were responsible for the small number of injuries encountered.

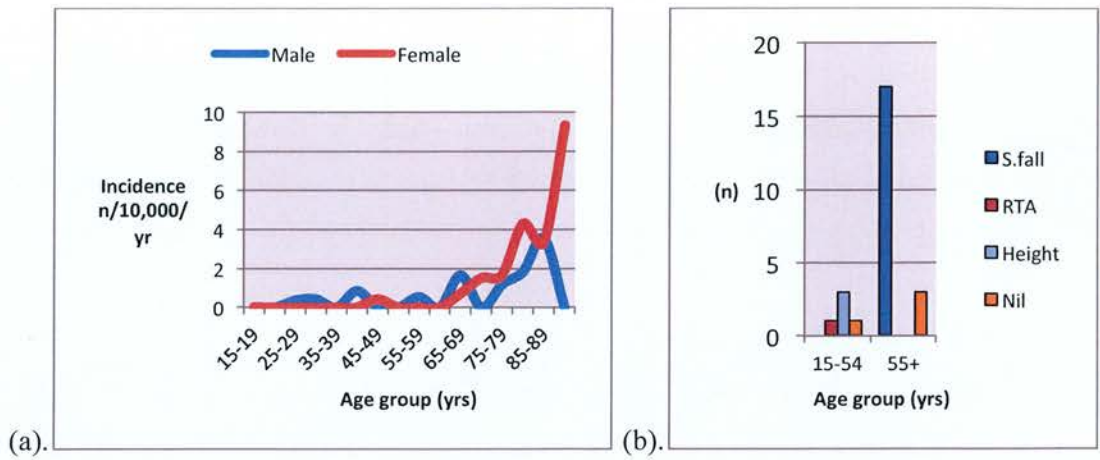


Figure 3.44 (a) The age- and gender-related incidence of subtrochanteric femoral fractures occurring in Edinburgh adults. (b) The modes of injury responsible for subtrochanteric femoral fractures, presented according to patient age group. (*RTA* = road traffic accident; *Height* = fall from height).

Diaphyseal fractures

Forty fractures occurred in the femoral diaphysis, in the absence of any prosthetic implant. The median age of patients was 68.5 years (R 18-96 yrs, IQR 47-81.5 yrs), representing the youngest of the three femoral shaft subgroups. Men were significantly younger than affected women ($p=0.001$, MWU test). In keeping with subtrochanteric fractures, the incidence of diaphyseal fractures increased with age in both genders, but the incidence was slightly higher in young men than young women, suggesting a type G curve (Fig. 3.45).

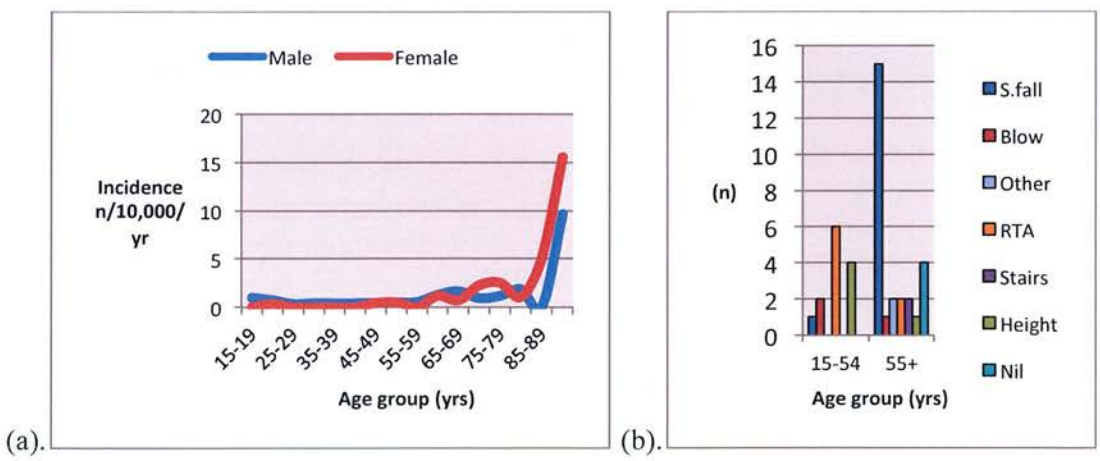


Figure 3.45 (a) The age- and gender-related incidence of femoral diaphyseal fractures occurring in Edinburgh adults. (b) The distribution of the modes of injury resulting in femoral diaphyseal fractures, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

The well documented pattern of high energy trauma affecting young men was evident in this series. Of the 13 cases occurring in 15 to 54 year olds, 12 resulted from high energy trauma and ten of these patients were men. More importantly, 67.5% of diaphyseal fractures were sustained by older adults (aged 55 yrs or more) and while a proportion of these injuries resulted from high energy trauma, the majority (63.0%) were caused by low energy transfer.

Periprosthetic femoral shaft fractures

Femoral fractures occurring around hip arthroplasty stems and above total knee arthroplasty components are increasing in frequency, partly due to the increasing number of primary and revision arthroplasties performed, but also due to the increasing age and fragility of patients undergoing this type of surgery²¹⁶. The literature suggests that more than three-quarters of these fractures are caused by low energy falls^{217,218}. The strategies employed in the management of periprosthetic femoral shaft fractures must take into consideration the site of the fracture, the stability of the implant and the quality of surrounding bone. As a result, many of the systems used for classifying these injuries attempt to describe these features. The Vancouver classification is the most widely used system for describing fractures around femoral stems²¹⁹. Type A fractures occur in the trochanteric region, affecting the greater (A_G) or lesser (A_L) trochanters. Type B fractures occur in the femoral shaft, at the level of the implant. They are subdivided into those associated with a stable implant (B1), an unstable implant (B2) and significant bone loss (B3). Type C fractures occur distant to the tip of the implant. A Swedish series of 321 periprosthetic femoral fractures reported 88% of fractures to be Vancouver type B. The average age of patients affected was 76 years²²⁰.

The Lewis and Rorabeck classification describes femoral fractures around total knee prostheses²²¹. These injuries may include femoral shaft fractures, but more commonly involve the distal femoral region. Type 1 fractures are undisplaced, and the integrity of the bone / prosthesis interface remains intact. Type 2 fractures are displaced, but the bone / prosthesis interface is unaffected. Type 3 fractures have a loose or failing prosthesis.

Thirty one periprosthetic fractures occurred, accounting for one-third of all femoral shaft injuries. Women (58.2%) were more commonly affected than men (41.8%), with no significant difference in age seen between the sexes. One (3.2%) mid-diaphyseal fracture occurred above a distal femoral locking plate. Another (3.2%) fracture was sustained proximal to a total knee arthroplasty (Lewis and Rorabeck type 1). The remaining injuries occurred in proximity to a femoral stem and were evenly distributed between the sexes. Ten fractures (32.3%) were Vancouver type B1, six (19.4%) were type B2 and 13 (41.9%) were

type C. These fractures occurred almost exclusively in patients aged 55 years or older, which was to be expected. The frequency of simple fall-related injury was 77.8% (Fig. 3.46), in keeping with the results presented from the Swedish series²¹⁸.

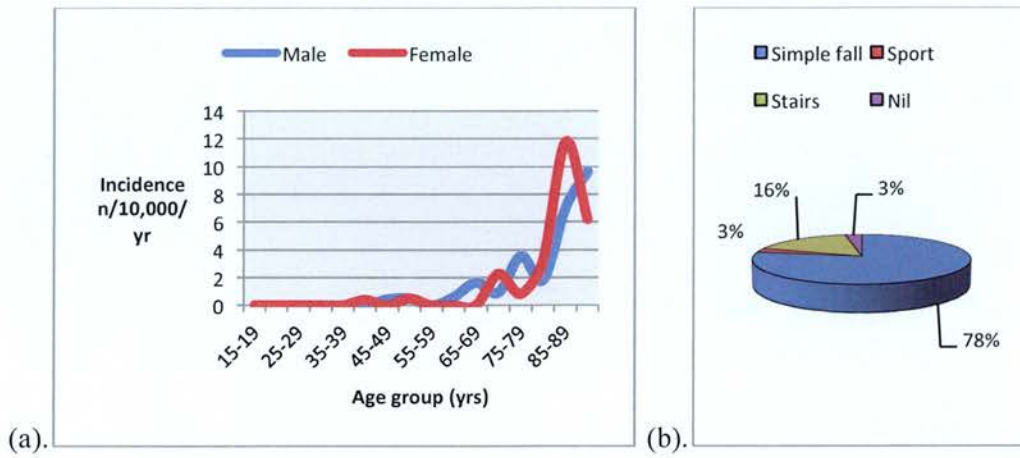


Figure 3.46 (a) The age- and gender-related incidence of periprosthetic femoral fractures occurring in Edinburgh adults. (b) The distribution of modes of injury involved in causing periprosthetic femoral fractures. (*Stairs* = fall down stairs).

3.13 Fractures around the knee

Fractures around the knee include those of the distal femur, tibial plateau, proximal tibia and fibula fractures (including avulsion fractures of the fibular head, tibial spines or tibial tuberosity) and fractures of the patella. The distal femur and proximal tibia are defined in the manner described by Muller¹³; the part of the bone that lies within a square whose base is the distance between the most medial and lateral boundaries of the bone on an anteroposterior radiograph.

A total of 173 fractures occurred in 170 patients, making up 6.7% of lower limb fractures and 2.5% of all adult fractures. Women accounted for 60.1%. There were three patients who suffered more than one knee fracture at presentation; three male patients sustaining injuries from RTAs. One 29 year old suffered bilateral tibial plateau fractures; a 27 year old man injured his distal femur and tibial plateau; another sustained ipsilateral tibial plateau and fibular head avulsion fractures. Table 3.46 shows the distribution of fractures around the knee. Men were noted to be significantly younger than women in all three subgroups ($p \leq 0.005$, MWU tests). There was a trend towards higher energy injury in fractures of the proximal tibia.

	Distal femur	Proximal tibia	Patella	p-value
Fractures (n, %)	36 (20.8)	82 (47.4)	55 (31.8)	-
Gender ratio (M:F, %)	36:64	44:56	33:67	$p=0.373^*$
Incidence (n/10,000/yr, 95% CIs)	0.7 (0.5-0.9)	1.5 (1.2-1.9)	1.0 (0.8-1.3)	-
Median age (yrs, IQR)	65 (45-86)	58 (34-76)	64 (42-72)	$p=0.224^k$
Men	49 (26.5-65)	37 (29-54)	42 (24-63.5)	$p=0.687^k$
Women	77 (55-87)	70.5 (56-82)	67 (60-79)	$p=0.215^k$
Mode of injury (n, %)				
Simple fall	26 (72.2)	37 (45.1)	40 (72.7)	$p=0.071^*$
Sports-related	1 (2.8)	6 (7.3)	2 (3.6)	
Direct blow	2 (5.6)	10 (12.2)	1 (1.8)	
Other	1 (2.8)	1 (1.2)	1 (1.8)	
RTA	4 (11.1)	19 (23.2)	5 (9.1)	
Fall down stairs	0	4 (4.9)	4 (7.3)	
Fall from a height	2 (5.6)	5 (6.1)	2 (3.6)	
Open injuries (n, %)	3 (8.3)	3 (3.7)	1 (1.8)	$p=0.295^*$

Table 3.46 The number, incidence and causative modes of injury involved in fractures around the knee joint, occurring in Edinburgh adults. The age-and gender-related distribution of affected patients is shown, as well as the frequency of open injuries. *Chi square test. ^kKW test. (RTA = road traffic accident).

Distal femur

Distal femoral fractures are not as common as fractures of the proximal femur or femoral shaft. Relatively little information exists in the literature with regards to their epidemiology. Arneson *et al* reported that they represented 30.6% of 402 non-hip femoral fractures over a twenty year period in Minnesota²⁰⁵. Rather like fractures of the femoral shaft, the authors described a bimodal distribution of fracture incidence, with high energy injuries occurring in young adult men and low energy injuries affecting older women. Other authors have recognised this pattern, but also commented on the association of distal femoral fractures as a complication of total knee arthroplasty, particularly when ‘notching’ of the anterior femoral cortex occurs²²².

Distal femoral fractures accounted for a small proportion of fractures overall and only 3.8% of 953 femoral fractures (Table 3.47). The 36 patients involved represented the youngest femoral fracture subgroup. There were 13 men with a median age of 49 years (IQR, 26.5-65 yrs) and 23 women with a median age of 77 years (IQR, 55-87 yrs). The incidence of 0.7/10,000/yr (95% CI 0.46-0.92) in the present series was higher than that reported for the same population in 2000 (0.5/10,000/yr)¹³². Although the proportion of men and women affected has remained unchanged, patients in the present series were older by four years.

Fracture type	Fractures (n)	Patients (n)	Frequency (%)	Age in yrs (median, IQR)	Gender ratio (M:F, %)
Proximal femur	821	809	11.9	83 (76-88)	27:73
Femoral diaphysis	96	96	1.4	75.5 (59.5-85)	54:56
Distal femur	36	36	0.5	65 (45-86)	36:64
All fractures	6,871	6,325	100	51 (28-74)	47:53

Table 3.47 The number and overall frequency of the three femoral fracture types described during the study period. The total number, age- and gender-related distribution of affected patients is also given.

The resultant fracture distribution curve (Fig. 3.47) highlights that the incidence of these fractures in men remained low throughout adult life, with a small number noted in the elderly. After the age of 65 years, the incidence in women increased. The best fit curve, according to Court-Brown and Caesar¹³², is the type E unimodal older female, suggesting that this fracture subtype should now be considered a fragility fracture. The distribution of injury modes supports this finding, as 100% of fractures in older adults occurred as a result of a simple fall from a standing height. Simple fall fractures accounted for 87.0% of fractures in women, but only 46.2% of fractures in men ($p=0.007$, Chi square test).

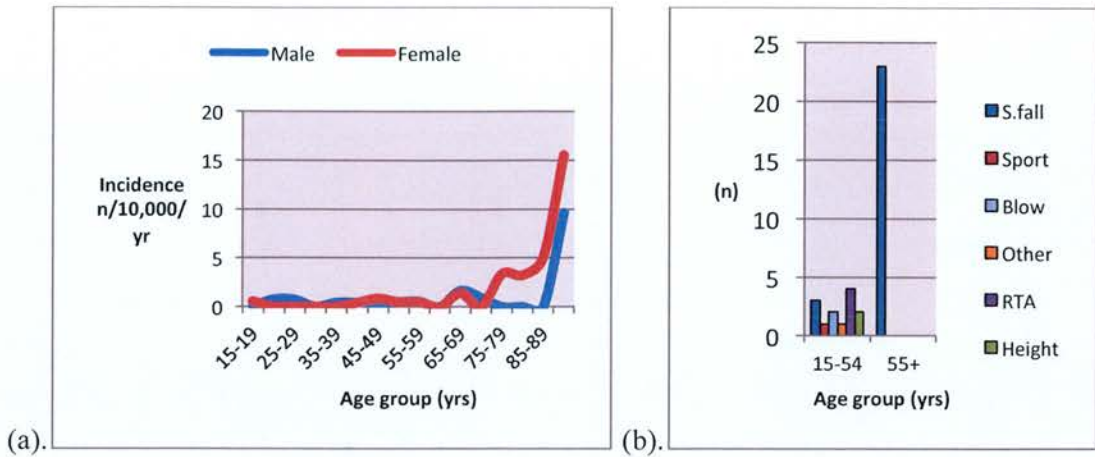


Figure 3.47 (a) The age- and gender-related incidence of distal femoral fractures occurring in Edinburgh adults. (b) The modes of injury involved in causing distal femoral fractures, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Height* = fall from height).

There is no universally accepted classification system for distal femoral fractures, but the AO system is preferred by many authors²²². It distinguishes between extra-articular (type A), partial articular (type B) and complete articular (type C) fractures. Metaphyseal comminution is also described (33-A2, A3 and C2 subtypes). The majority of fractures encountered in the present series were AO type A (n=21, 75%). Five of these injuries were apophyseal avulsion fractures, while the remainder were true supracondylar fractures. There were four type B fractures, including a coronal fracture of the femoral condyle (first described by Hoffa in 1904²²³). In keeping with the literature, all four type B injuries resulted from high energy trauma and occurred in a slightly younger patient age group²²⁴. Four type C fractures occurred in four elderly women, and all resulted from a low energy fall. Metaphyseal comminution was present in 25% of type A and C fractures.

Proximal tibia

Approximately half of all fractures around the knee involved the proximal tibia. The frequency of open fractures was low (n=3, 3.7%). Four fractures involved the proximal tibial metaphysis, without extension into the articular surface (Table 3.48, next page). There were 13 avulsion fractures occurring in a younger patient subgroup, four of which resulted from sporting activity. Two tibial tuberosity fractures resulted from simple falls from a standing height. The remainder of avulsion fractures involved the tibial spines (ACL=9, PCL=2). These were caused by a variety of injury modes, but five were considered to involve high energy trauma.

	Metaphysis	Avulsions	Plateau	p-value
Fractures (n, %)	4 (4.9)	13 (15.9)	65 (79.2)	-
Gender ratio (M:F, %)	50:50	69:31	42:58	p=0.186*
Median age (yrs, IQR)	63.5 (40-91)	33 (25.5-61.5)	59 (36.5-77.5)	p=0.057 ^k
Men	34, 58	33 (25.5-58)	37 (29-52)	p=0.774 ^k
Women	69, 98	46 (22-72)	73 (57-82)	p=0.130 ^k
Mode of injury (n, %)				
Simple fall	1 (25.0)	7 (53.8)	29 (44.6)	p=0.004*
Sport / RTA / Height	1 (25.0)	5 (38.5)	24 (36.9)	
Open injuries (n, %)	1 (25.0)	0	2 (3.1)	p=0.057*

Table 3.48 The number and frequency of fractures of the proximal tibia, occurring in Edinburgh adults, according to anatomical fracture location. The age- and gender-related distribution of affected patients is given, as well as the proportion of fractures resulting from a simple fall, or higher energy trauma. *Chi square test. ^kKW test. (*Sport* = sporting activity; *RTA* = road traffic accident; *Height* = fall from a height).

Fractures of the tibial plateau constituted the largest subgroup. These fractures are known to be a diverse group of injuries, varying in severity from low energy simple fractures to severely comminuted fractures resulting from high energy violence. Plateau fractures occur almost exclusively in adults, and according to the literature the highest incidence in male patients occurs between 20 and 50 years, with a large proportion of these resulting from high energy trauma. In women the incidence rises with advancing age, suggesting an association with osteoporosis²²⁵.

Anderson *et al* have shown that the pattern of fracture results from a combination of the forces applied and the quality of the bone²²⁶. Therefore, it seems logical that high energy injury modes will result in more severe and complex fracture patterns. Two studies examining the results of operative treatment of bicondylar or total articular tibial plateau fractures found that in excess of 80% of these severe injuries resulted from RTAs^{227, 228}. At the opposite end of the injury spectrum, Keating analysed tibial plateau fractures in Edinburgh adults aged 60 years or more, and found 58% to be due to a simple fall from a standing height²²⁹. Split-depression (32%) and pure depression (20%) fractures of the lateral plateau were most common.

The system proposed by Schatzker⁶³ (Fig. 3.48), and the AO and OTA (see the Appendix) classification¹⁴ are the two most widely used classification systems for tibial plateau fractures. They both attempt to group fractures with similar morphology together, with the aim of guiding treatment and predicting outcome. In order to do this successfully, classification systems require a reasonable degree of reliability and reproducibility. Walton *et al* examined both classification systems²³⁰. Overall, they found the AO system to be more

reliable, but reported that interobserver reliability and intraobserver reproducibility both decreased when moving from AO typing (41-A, B or C) to AO grouping (A1, A2 *etc.*) and beyond (A1.2, A1.3 *etc.*). Walton, and other authors²³¹, have indicated that the overall reliability of tibial plateau classification systems is moderate (a kappa coefficient of 0.4-0.6 according to the criteria of Landis and Koch²⁴).

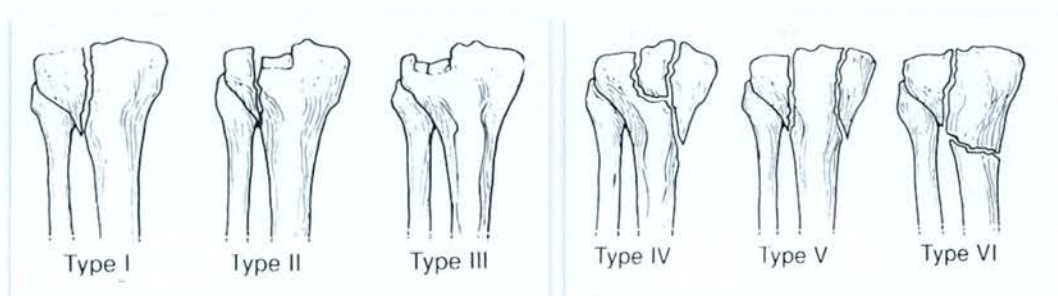


Figure 3.48 The Schatzker classification⁶³ of tibial plateau fractures. Type I – split fracture; type II – split depression fracture; type III – depression fracture; type IV – involving the medial condyle; type V – bicondylar fracture; type VI – complete articular fracture. (Reproduced with permission from the Association of Bone and Joint Surgeons).

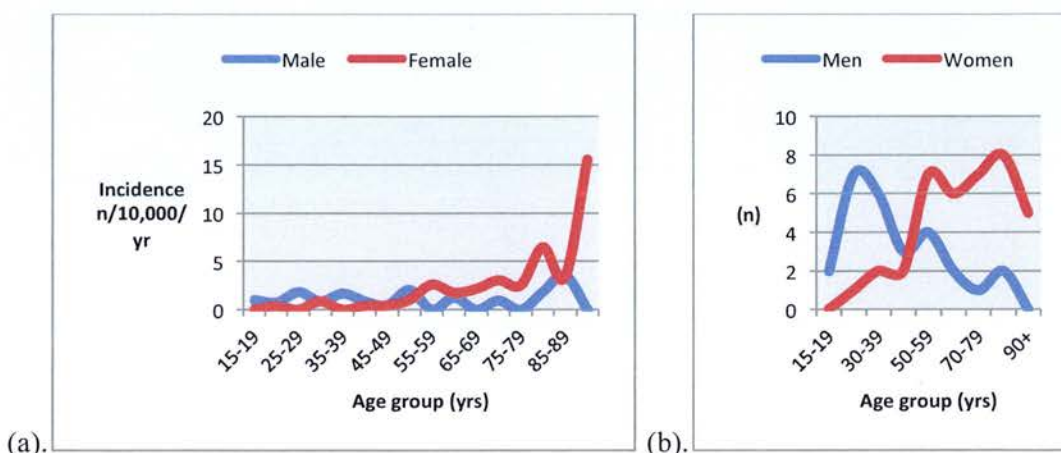


Figure 3.49 (a) The age- and gender-related *incidence* of tibial plateau fractures occurring in Edinburgh adults. (b) The actual *number* of tibial plateau fractures encountered, and presented according to patient age and gender.

Sixty five tibial plateau fractures occurred in 64 patients. A 29 year old man suffered bilateral tibial plateau fractures as a passenger in a RTA. The median age of all patients was 59 years (IQR, 36.5-77.5 yrs) with a range from 15 to 96 years. Tibial plateau fractures were more commonly seen in women (58.5%) than in men (41.5%). The median age of men was 37 years (IQR, 29-52 yrs). They represented a significantly younger group than women, whose median age was 73 years (IQR, 57-82 yrs), ($p < 0.001$, MWU test). Tibial plateau

fractures accounted for 0.9% of all acute adult fractures and 2.5% of lower limb fractures. The overall incidence was 1.2/10,000/yr (95% CI, 0.9-1.5). The incidence in women (1.3/10,000/yr, CI 0.9-1.8) was slightly higher than that in men (1.0/10,000/yr, CI 0.7-1.5).

Figure 3.49 (previous page) shows the gender-related incidence, and fracture number, curves for tibial plateau fractures. In keeping with a recent review²²⁵, the incidence in women increased steadily with age while that of men was bimodal (a type G curve, according to Court-Brown and Caesar¹³²). The overall incidence has increased 10% from that reported in 2000, when the rate was 1.08/10,000/yr¹³². Patients from the present series (59 years, IQR 36.5-77.5) were significantly older than those in 2000 (41 years, IQR 30-63 yrs), ($p=0.007$, MWU test). This is predominantly due to the increased incidence seen in female patients (1.32 from 0.99), with a simultaneous reduction in male incidence (1.04 from 1.19). Figure 3.50 illustrates the differences seen in gender-related fracture incidence between 2000 and 2007/08.

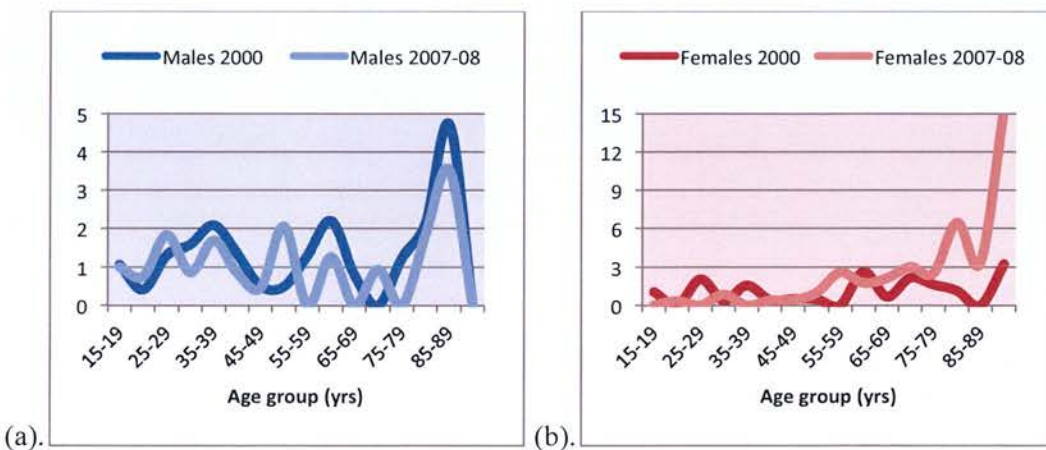


Figure 3.50 The age-related incidence (n/10,000/yr) of tibial plateau fractures occurring in men (a) and women (b) in Edinburgh, during the year 2000 and between 2007 and 2008.

Table 3.49 (next page) shows the distribution of these injuries according to the Schatzker classification system⁶³. According to the literature, younger patients tend to suffer split fractures with less depression, whereas older patients with poorer bone quality have a greater compression component²²⁵. Statistical analyses of the differences found between groups were hampered by the relatively small numbers recorded, but type 1 fractures did occur in a younger patient group with a higher proportion of men. Type 3 (depression) fractures affected a predominantly elderly female group. Increasing fracture complexity was associated with a higher proportion of high energy trauma and a greater percentage of

patients suffering associated skeletal injury. Of note, fractures involving the medial condyle and complete articular injuries (types 4, 5 and 6) were not only sustained by young men in high energy trauma, but also by a significant number of elderly women after a simple fall from a standing height.

	Schatzker type					p-value
	I	II	III	IV	V or VI	
Fractures (n, %)	14 (21.5)	17 (26.2)	9 (13.8)	15 (23.1)	10 (15.4)	-
Gender ratio (M:F, %)	50:50	29:71	33:67	53:47	40:60	p=0.368*
Median age (yrs, IQR)	51.5 (34-66)	59 (40-77)	76 (57-88)	53 (29-80)	55.5 (39-70)	p=0.157*
Men	36 (31-51)	46 (27-84)	52 (34-62)	34 (25.5-50)	35.5 (22-49)	p=0.809*
Women	60 (52-79)	61 (47-73.5)	82.5 (76-93)	80 (62-92)	65.5 (56-84)	p=0.080*
% RTA / Height	21.4	29.4	33.3	33.3	50.0	p=0.580*
% with associated fractures	14.3	29.4	44.4	13.3	50.0	p=0.109*

Table 3.49 The number and frequency of tibial plateau fractures, occurring in Edinburgh adults, according to the Schatzker classification system⁶³. The age- and gender-related distribution of affected patients is given. The proportion of injuries presenting with associated fractures, and those sustained from high energy trauma, are also shown. *Chi square test. ^kKW test. (*RTA* = road traffic accident; *Height* = fall from a height).

Patella

A review of the literature suggests that fractures of the patella account for approximately 1% of all fractures^{232,233}. They are uncommon in children and adolescents, although the 'sleeve fracture' variant is well documented in younger age groups²³⁴. As a consequence of its position in front of the knee joint, and its relatively thin overlying soft tissue envelope, the patella is prone to injury by direct force. Examples include a fall onto the flexed knee, or an anterior blow from the dashboard in patients involved in RTAs. The frequency of open injury is more common in high energy direct blow accidents, although it remains low overall²³⁵. Indirect injuries can also occur, typically resulting from forceful quadriceps contraction with the knee flexed. The classification of patellar fractures is descriptive in nature and is based upon the injury pattern seen, the degree of displacement, or the mechanism of injury. The AO system used in the present series is an example of a descriptive system. The fracture pattern alone has not been shown to correlate well with outcome²³². Perhaps for this reason, the literature has been more concerned with reported outcomes based on the treatment employed²³⁶⁻²³⁸.

Fifty five patellar fractures occurred during the study period, accounting for 31.8% of fractures around the knee, 2.1% of lower limb fractures and 0.8% of all adult fractures. One open fracture occurred (1.8%) and resulted from a simple fall from a standing height in a 41 year old care assistant. Two-thirds of affected patients were women. The median age of women (67 yrs, IQR 60-79 yrs) was significantly older than men (42 yrs, IQR 24-63.5 yrs), ($p=0.005$, MWU test). The resultant distribution curve is type A, showing a unimodal peak in older women and younger men, although a small number of injuries was noted in elderly male patients (Fig. 3.51). Simple fall fractures were more commonly seen in older adults, and occurred more often in women (83.8%) than men (50.0%). Fractures resulting from RTAs or falls from a height accounted for 33.3% of injuries in younger adults, but only 2.7% of injuries in older adults ($p=0.006$, Chi square test plus Yates' correction).

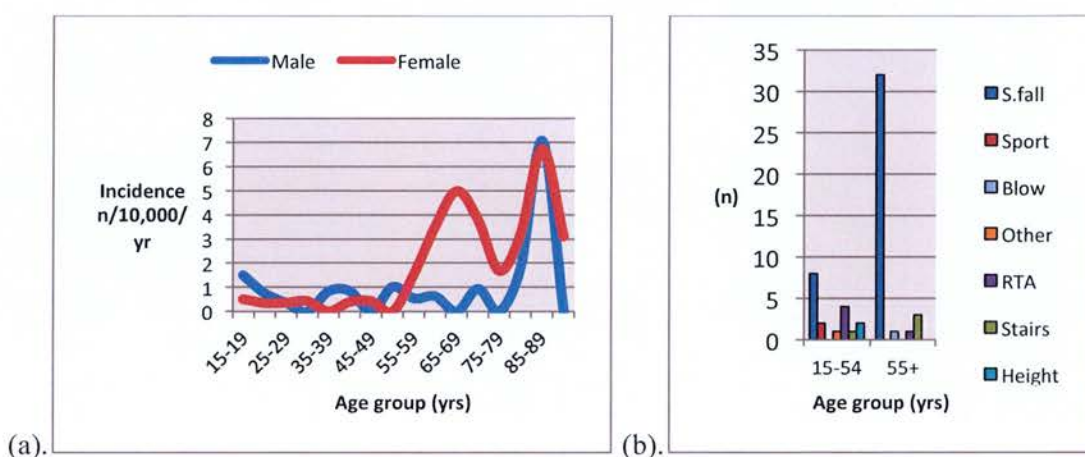


Figure 3.51 (a) The age- and gender-related incidence of fractures of the patella occurring in Edinburgh adults. (b) The modes of injury involved in causing patellar fractures, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

Table 3.50 (next page) shows the distribution of fracture patterns seen. Overall, 38.2% of patellar fractures were undisplaced; a figure very similar to that presented in a recent review on the subject²³². Displacement was more commonly encountered with stellate and transverse fracture configurations. The majority of avulsion fractures were minimally or non-displaced, suggesting continued integrity of the extensor retinaculum. Vertical fractures are rare injuries and are said to result from direct compression of the patella in the hyperflexed knee²³⁹. No significant difference was seen between fracture types with regards to the injury mode responsible ($p=0.821$, Chi square test).

	Avulsion	Stellate	Transverse	Vertical	All	p-value
Fractures (n, %)	8 (14.5)	9 (16.4)	36 (65.5)	2 (3.6)	55 (100)	-
Gender ratio (M:F, %)	50:50	22:78	33:67	0:100	33:67	$p=0.473^*$
Median age (yrs, IQR)	46 (24-68)	56 (24-70)	66.5 (54-80)	61 & 64	64 (42-72)	$p=0.141^k$
% displaced	12.5	88.9	69.4	0	61.8	$p=0.002^*$

Table 3.50 The number, anatomical configuration and frequency of displacement of patellar fractures occurring in Edinburgh adults. Details of the age- and gender-related distribution of affected patients are also shown. *Chi square test. ^kKW test.

3.14 Fractures of the tibia and fibula

Diaphyseal fractures of the tibia represent the commonest long bone fracture type. They have generated a tremendous amount of interest and research in the orthopaedic literature. Their association with high energy trauma, a young male population and occasional severe bony and soft tissue injury is well recognised²⁴⁰. Tibial shaft fractures often occur with an associated fibular fracture, but they may also present in isolation. The presence of an intact fibula has previously been associated with delayed union, although this was reported before the routine use of intramedullary nailing for the treatment of these injuries²⁴¹. Fracture of the fibula, in the absence of a tibial fracture, is an uncommon injury and relatively little information is available regarding its epidemiology.

One hundred and seven fractures of the tibia and fibula occurred in 106 patients. Bilateral tibial shaft fractures were sustained by a male pedestrian involved in a RTA. The incidence of tibial shaft fractures was three times higher than that of isolated fibular injuries. Otherwise, these injury subtypes appeared to be remarkably similar in terms of the gender ratio, age of affected patients and the frequency of sport-related or high energy injury (Table 3.51). The frequency of open tibial fractures (21.8%) was greater than for any other fracture type recorded during the study period.

	Tibial shaft	Isolated fibula	p-value
Fractures (n, %)	78 (72.9)	29 (27.1)	-
Gender ratio (M:F, %)	81:19	72:28	p=0.604*
Incidence (n/10,000/yr, 95% CIs)	1.4 (1.1-1.8)	0.5 (0.3-0.8)	-
Median age (yrs, IQR)	31 (22-50.5)	39 (26-48)	p=0.549**
Men	28 (21-45.5)	29 (23-45)	p=0.636**
Women	53 (31-83)	49 (37-70.5)	p=0.691**
Mode of injury (n, %)			
Simple fall	19 (24.4)	5 (17.2)	p=0.747*
Sports-related	24 (30.8)	10 (34.5)	
Direct blow	9 (11.5)	4 (13.8)	
Other	4 (5.1)	2 (6.9)	
RTA	16 (20.5)	8 (27.6)	
Fall down stairs	2 (2.6)	0	
Fall from a height	4 (5.1)	0	
% with multiple fractures	14.1	13.8	p=1*
Open injuries (n, %)	17 (21.8)	0	p=0.015*

Table 3.51 The number, incidence and modes of injury responsible for fractures of the tibial and fibular diaphyses, occurring in Edinburgh adults. The age- and gender-related distribution of affected patients is shown. The frequency of open injuries and associated fractures is also given. *Chi square test. **MWU test.

Tibial shaft fractures

The AO group reported on 4,889 tibial shaft fractures, treated by a large group of hospitals in northern Europe between 1980 and 1989. The majority of patients affected were young men and many fractures were caused by high energy violence. They noted no increase in elderly fracture numbers over that time period, but they were unable to calculate incidence as part of their report²⁴².

Bengner *et al* analysed 363 fractures in patients aged ten yrs and older, from 1979-83 in Sweden²¹⁰. They noted an overall incidence of 4.4/10,000/yr. The rate was higher in men (6.6/10,000/yr) than in women (2.5/10,000/yr), and the incidence in patients over 70 years of age was 2.9/10,000/yr. The authors noted a small increase in the fracture rate in elderly women when compared with the 1950s. Emami and colleagues studied tibial shaft fractures over two separate five-year periods in Sweden²⁴³. They found a decrease in male incidence due to reduced numbers of high energy injuries, but an increase in female incidence due to the increased number of low energy fractures suffered by older women.

Court-Brown and McBirnie reviewed 523 tibial diaphyseal fractures in Edinburgh patients aged 12 years or older²⁴⁰. The average patient age over the three-year period of study (1988 to 1990) was 37.2 years. Overall, 23.5% of tibial fractures were open. Gustilo grade 3 fractures¹¹² accounted for 59.8% of open injuries, underlining the association of tibial shaft fractures with potentially severe soft tissue trauma. Court-Brown and Caesar reported on adult fractures in the Edinburgh population ten years later¹³². Fractures in men remained predominant, and the average patient age was unchanged (median 37 years). The overall incidence was 2.0/10,000/yr, and was higher in men (2.5/10,000/yr) than in women (1.5/10,000/yr). The frequency of open fractures had fallen to 16.7%, although a high proportion of grade 3 injuries were still encountered (58.8%).

Seventy eight fractures of the tibial diaphysis occurred over the one-year study period, accounting for 3.0% of lower limb fractures and 1.1% of all fractures. Men (n=61) were affected more often than women (n=16), and were noted to be significantly younger ($p < 0.001$, MWU test). As a result, the incidence was significantly higher in men (2.4/10,000/yr, 95% CI 1.9-3.0) than in women (0.6/10,000/yr, 0.3-0.9). Figure 3.52 (next page) shows the gender-related differences in fracture incidence. The fracture rate remained low in all female age groups although a small increase was noted in the elderly. In keeping with many previous studies, the peak male incidence was seen in teenagers^{132, 210, 240, 243}.

Figure 3.53 shows the incidence curves generated over a period of 20 years from the Edinburgh trauma unit. The overall incidence of these fractures has fallen over this time, although the distribution pattern has changed very little. In contrast to fractures of the tibial plateau, the incidence of tibial shaft fractures in elderly women has not risen, despite the aging Scottish population. As has been previously suggested by Bengner *et al*²¹⁰, tibial shaft fractures appear more resistant to the factors that cause an increased fracture risk in the elderly.

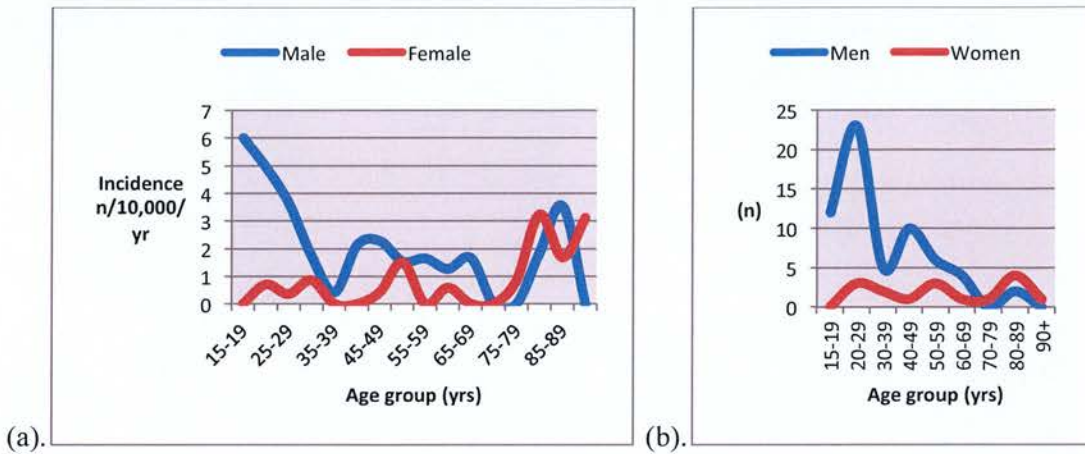


Figure 3.53 (a) The age- and gender-related *incidence* of tibial diaphyseal fractures occurring in Edinburgh adults. (b) The actual *number* of tibial diaphyseal fractures encountered, and presented according to patient age and gender.

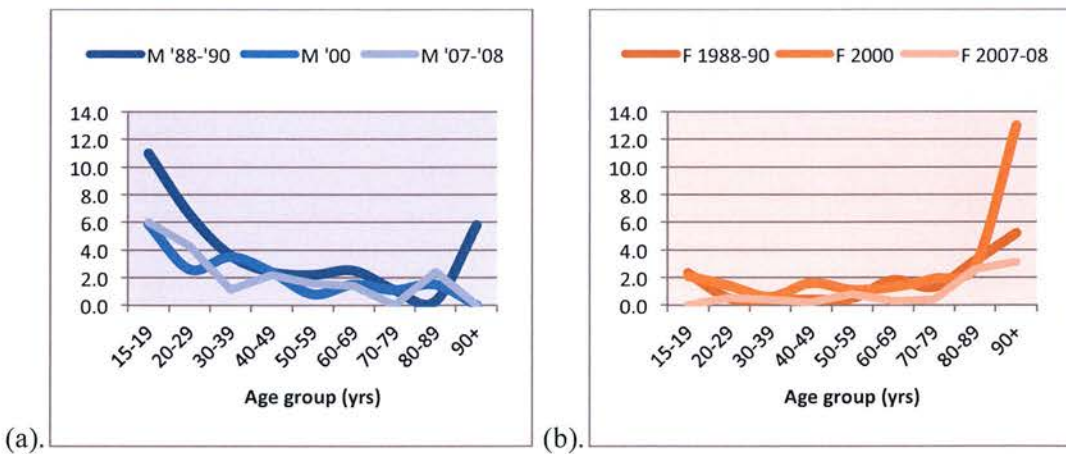


Figure 3.54 The age-related incidence (n/10,000/yr) of tibial diaphyseal fractures occurring in men (a) and women (b) in Edinburgh, between 1988 and 1990 (Court-Brown and McBirnie²⁴⁰), during the year 2000 (Court-Brown and Caesar¹³²), and in the present series (2007-08).

The most comprehensive classification system for tibial shaft fractures is that originally described by the AO Foundation, and since adopted and modified by the OTA¹⁴ (presented at the Appendix). This is a radiographic classification, based upon anteroposterior and lateral radiographs, and consists of three fracture types (A, B and C) subdivided into a total of nine groups (42-A1, A2, A3, B1 *etc.*). Each group is then further divided into three subtypes. Types A, B and C represent simple, wedge and complex fracture patterns, respectively. The groups (1, 2 and 3) refer to the orientation of the fracture line(s), and the subgroups (B2.1, 2.2, 2.3 *etc.*) denote increasing complexity of the fracture, including the presence or absence of a fibula fracture. The AO system attempts to accurately define and describe fractures of increasing severity and complexity, but it has not been shown to be particularly useful in predicting clinical outcome^{244, 245}. The commonest tibial diaphyseal fractures encountered in the present series were groups 42-A1 and 42-A3 (Table 3.52).

Type A		Type B		Type C	
A1	29	B1	5	C1	0
A2	6	B2	6	C2	1
A3	25	B3	4	C3	2
Total (n, %)	60 (76.9)	Total (n, %)	15 (19.3)	Total (n, %)	3 (3.8)

Table 3.52 The number and frequency of fractures of the tibial shaft, occurring in Edinburgh adults, arranged according to AO fracture types and groups. (See the Appendix for a comprehensive description of each group).

Open fractures were classified by the system proposed by Gustilo and Anderson¹¹², and later further modified by Gustilo¹¹³. The classification is based upon the degree of soft tissue damage, and progresses from grade 1 to grade 3. Grade 3 injuries are further divided into those with adequate soft tissue coverage, inadequate coverage and the presence of associated vascular injury requiring repair.

The commonest injury mode responsible for tibial shaft fractures was sporting activity (n=24, 30.8%). Football accounted for 14 fractures, rugby for three and motocross a further three. Men were more commonly involved than women, and sports-related fractures represented the youngest group (Fig. 3.54, next page). A simple fall from a standing height caused 19 fractures (24.4%) in the oldest patient group, and men and women were equally represented. Road traffic accidents caused 16 injuries (20.5%) in a predominantly younger male group. Patients were most often pedestrians struck by motor vehicles (n=9, 56.3%), but a number of injuries involved motorcyclists (n=6, 37.5%) and one (6.2%) was suffered by a vehicle occupant.

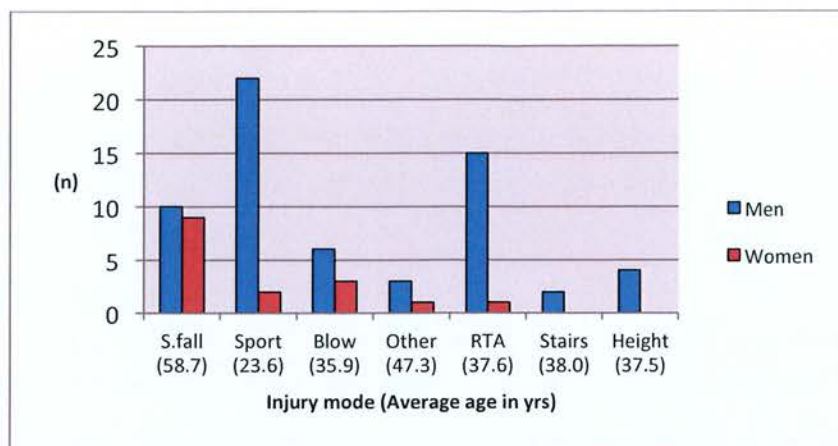


Figure 3.54 The number of men and women in Edinburgh sustaining fractures of the tibial diaphysis, arranged according to the mode of injury involved. The mean age of patients in each category is also shown. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

	Men (n=61)	Women (n=16)	Both (n=77)	p-value
Fractures (n, %)	62 (79.5)	16 (20.5)	78 (100)	-
AO type				
A	46 (74.2)	14 (87.5)	60 (76.9)	p=0.463*
B	13 (21.0)	2 (12.5)	15 (19.3)	
C	3 (4.8)	0	3 (3.8)	
Fracture location				
Proximal one-third	2 (3.2)	0	2 (2.6)	p=0.509*
Middle one-third	29 (46.8)	6 (37.5)	35 (44.9)	
Distal one-third	28 (45.2)	10 (62.5)	38 (48.7)	
Extensive	3 (4.8)	0	3 (3.8)	
Open fractures (n, %)	13 (21.0)	4 (25.0)	17 (21.8)	p=0.728*
Gustilo & Anderson (%)				
Grade 1	23.1	25.0	23.5	p=0.005*
Grade 2	7.7	50.0	17.6	
Grade 3	69.2	25.0	58.8	
% from RTA / Height	30.6	6.3	25.6	p=0.095*
% intact fibula	24.2	12.5	21.8	p=0.312*

Table 3.53 The number and frequency of tibial diaphyseal fractures, occurring in male and female patients in Edinburgh. The gender-related distributions of AO fracture types, fracture locations, open fractures, high energy injuries and intact fibulae are shown. *Chi square test, 'p-values' have been calculated for comparisons between the genders. (*RTA* = road traffic accident; *Height* = fall from a height).

Simple fracture types were more commonly seen in women than in men (Table 3.53, above), and middle and distal one-third injuries were more common than those of the proximal one-third. One-fifth of fractures featured an intact fibula, and 52.3% of these resulted from sporting activity. A comparative analysis of fracture patterns between the genders confirmed the trend towards higher energy fractures and more severe open injuries in men.

Isolated fractures of the fibula

For the purposes of the present analysis, an isolated fibular fracture was defined as a fracture of the fibula in the absence of an ipsilateral tibial fracture or apparent ankle injury. There were 29 such fractures and they accounted for 27.1% of tibia and fibula fractures, 1.1% of lower limb fractures and 0.4% of all adult fractures. There were no open fractures. Twenty one (72.4%) patients were men, and they represented a significantly younger group than women (median age 29 vs. 49 years), ($p=0.015$, MWU test). Isolated fibular fractures occurred in young adults: only three cases were identified in patients aged 55 years or more. The fracture distribution curve illustrates this unimodal distribution (Fig. 3.55).

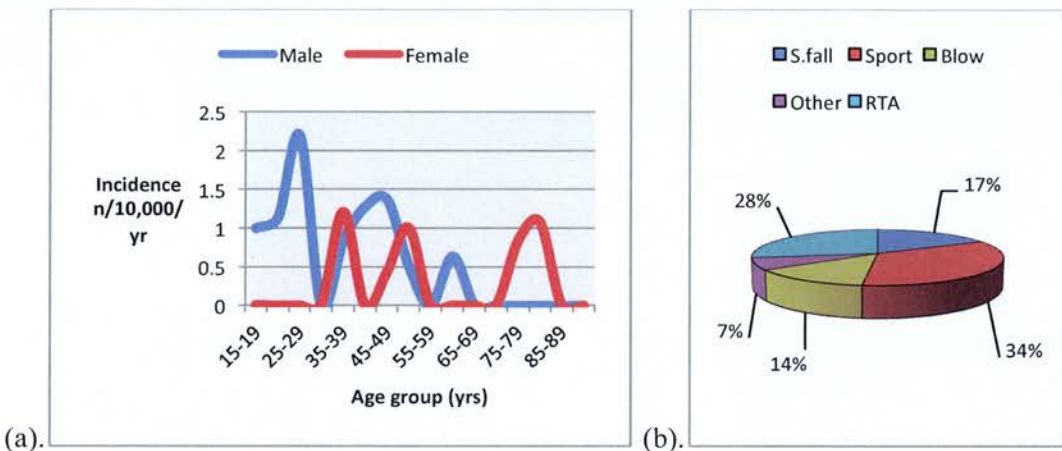


Figure 3.55 (a) The age- and gender-related incidence of isolated fractures of the fibula occurring in Edinburgh adults. (b) The distribution of modes of injury responsible for isolated fibular fractures. (*Blow* = direct blow; *RTA* = road traffic accident).

One-third of fractures resulted from sporting activity and a slightly smaller proportion were sustained from RTAs. The frequency of low energy trauma was low, particularly when compared with most other adult fracture types. Seven fractures involved the fibular head. One was caused by a direct blow, three were associated with sports-related soft tissue knee injuries, and three occurred during RTAs. Eleven fractures involved the fibular neck or proximal one-third of the fibular diaphysis. Eight of these injuries involved a documented direct lateral blow; three injuries involved a simple spiral fracture pattern, with a history of a twisting mechanism. The remaining 11 cases involved the middle one-third of the diaphysis and were associated with a documented history of a lateral blow or medially directed force acting upon the fibula.

Associated skeletal injuries were seen in four patients, all of whom had suffered high energy trauma. A 44 year old man sustained open fractures of the ipsilateral femoral shaft and midfoot, and a closed injury of the ipsilateral femoral neck. A 35 year old woman suffered bilateral closed distal radius fractures and a fracture of the pubic ramus. A 27 year old man sustained ipsilateral fractures of the femoral condyle and medial tibial plateau. These three patients had been involved in motorcycle accidents, and had also suffered significant soft tissue injuries to the ipsilateral knee. The fourth patient, a 25 year old male pedestrian, suffered ipsilateral midshaft fractures of the radius and ulna after being struck by a bus.

Fractures of the fibula in the absence of significant injury to the ipsilateral tibial diaphysis or ankle are rare. In the present series of acute adult fractures, isolated fibular fractures were less common than fractures of the tibia and fibula combined. However, they were more common than the isolated tibial shaft fracture. Sporting injuries and RTAs accounted for two-thirds of the injuries seen and young men were most frequently involved.

Close analysis of the reported injury modes reveals that isolated fractures of the fibula were seen under three sets of conditions. Firstly, a proportion of fibular head fractures represented avulsion fractures of the lateral ligamentous structures of the knee. These were often associated with high energy injuries such as road traffic accidents. Secondly, a group of fractures involved the fibular neck or proximal fibular diaphysis. These may have been examples of the type of supra-syndesmotric ankle injury described by Pankovich²⁴⁶. He reported a group of proximal fibular fractures associated with rupture of the anterior tibio-fibular ligament, but with preservation of the deltoid ligament. Stress radiographs of the ankle mortise, as described by McConnell *et al*, can be used to identify subtle syndesmotric injury²⁴⁷. Finally, a number of true isolated injuries occurred in the absence of knee or ankle pathology, and resulted from a direct blow to the lateral aspect of the leg.

3.15 Fractures of the distal tibia and ankle

The pattern of fractures affecting the tibial plafond or ankle mortise is dependent upon the direction and rate of application of the applied force, and the position of the foot at the time of loading^{65,66}. Ankle fractures occur typically as a result of relatively low energy indirect rotational forces, whereas intra-articular fractures of the distal tibial weight-bearing surface are the result of axial loading forces²⁴⁸. The talus is forced proximally into the distal tibial 'plafond' (from the French for 'ceiling'), causing a compressive fracture of the articular surface, often with an anterior or posterior shear component. The term 'pilon fracture' also originates in France: a term used to describe the mechanism of fracture. The French radiologist Destot suggested in 1911 that the talus acting upon the tibial plafond was rather like a pestle (or 'pilon' in French) acting upon a mortar²⁴⁹.

Six-hundred and eighty six fractures of the distal tibia and ankle occurred in 681 patients, and their distribution is shown in Table 3.54. Together they accounted for 26.8% of lower limb fractures and 10.0% of all fractures. One patient suffered bilateral distal tibial fractures following a fall from a height. Three patients suffered bilateral ankle fractures (two from high energy trauma) and a fourth sustained a contralateral low energy ankle injury many months after the index fracture.

	Distal tibia	Ankle	p-value
Fractures (n, %)	55 (8.0)	631 (92.0)	-
Gender ratio (M:F, %)	65:35	46:54	p=0.014*
Incidence (n/10,000/yr, 95% CIs)	1.0 (0.8-1.3)	11.6 (10.7-12.5)	-
Median age (yrs, IQR)	40 (27-52.5)	50 (31-64)	p=0.003**
Men	36 (26-45)	40 (26-54)	p=0.074**
Women	54 (31-69)	59 (44-69)	p=0.360**
Mode of injury (n, %)			
Simple fall	17 (30.9)	394 (62.4)	p<0.001*
Sports-related	9 (16.4)	94 (14.9)	
Direct blow	4 (7.3)	14 (2.2)	
Other	1 (1.8)	38 (6.0)	
RTA	5 (9.1)	24 (3.8)	
Fall down stairs	2 (3.6)	47 (7.4)	
Fall from a height	15 (27.3)	20 (3.2)	
Nil / spontaneous	2 (3.6)	0	
% with multiple fractures	3 (5.6)	37 (4.3)	p=0.933*
Open injuries (n, %)	1 (1.8)	5 (0.8)	p=0.977*

Table 3.54 The number and frequency of fractures affecting the distal tibia and ankle mortise, occurring in Edinburgh adults. The age- and gender-related distribution of affected patients is shown, as well as the causative modes of injury involved. *Chi square test. **MWU test. (RTA = road traffic accident).

Distal tibial fractures

Distal tibial fractures include the (partial or complete articular) pilon fractures of the tibial plafond as well as extra-articular fractures of the distal tibial metaphysis. In keeping with many fracture types, a spectrum of injury modes is evident ranging from high energy trauma in younger adults to low energy fractures in the elderly. Ruedi was one of the first authors to draw attention to tibial plafond fractures, and noted in his Swiss series that many injuries were the result of downhill skiing and other high energy mechanisms⁶⁵. He noted the frequency of open fractures was 3% to 6%. More recent studies, concentrating on the challenging management of high energy fractures from RTAs and falls from a height, have found open fractures in 12% to 40% of cases^{250,251}. These authors have reported that men were involved more often than women and 25% to 50% suffered multiple injuries of the skeleton and other major organ systems.

There are number of classification systems used to describe distal tibial fractures. Ruedi and Allgower devised the most well known system for fractures of the plafond, but did not include extra-articular fractures⁶⁵. Their classification describes three fracture types based upon displacement and the degree of comminution of the articular surface (Fig. 3.56). Type I are undisplaced; type II demonstrate displaced articular fragments, without comminution; type III involve displacement and comminution of articular fracture fragments.

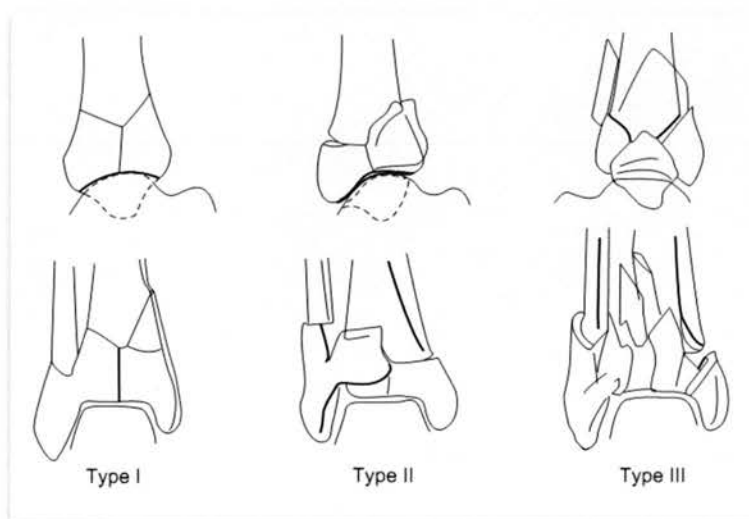


Figure 3.56 The Ruedi and Allgower classification system⁶⁵ for fractures of the tibial plafond, including type I undisplaced fractures, type II displaced fractures, and type III displaced and comminuted fractures.

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The most commonly used classification system is that of the AO and OTA groups (see the Appendix)¹⁴. It describes all fractures of the distal tibial region, including extra-articular (type A) fractures and tibial plafond fractures (type B and type C). Subdivisions of each type attempt to delineate fracture position, direction and comminution. Swiontkowski and colleagues demonstrated moderate interobserver agreement using the AO system in terms of describing fracture types (A, B and C), but noted poorer levels of agreement when discerning fracture grouping (A1, A2 *etc.*) and subtyping (B1.1, 1.2, *etc.*)²⁵². A study by Martin *et al* agreed with the findings of Swiontkowski²⁵³. The authors also found the AO system to be superior to the classification of Ruedi and Allgower in terms of reliability and reproducibility. Martin did not find the use of CT imaging to be of benefit in classification, but it proved effective in determining the percentage of articular surface involvement.

Fifty five fractures of the distal tibia were recorded, and this number included intra- and extra-articular injuries. They accounted for 2.1% of lower limb fractures and 0.8% of all fractures. Two-thirds of the 54 patients affected were male. Men were approximately 18 years younger than affected women ($p=0.003$, MWU test). The incidence in men was 1.4/10,000/yr (95% CI, 1.0-1.9) and was double that of women (0.7/10,000/yr, 95% CI 0.4-1.0). The fracture distribution curve reflects this gender-related pattern of presentation (Fig. 3.57). Peak male incidence was seen in teenagers and then again in mid-adulthood. Female incidence was highest after the age of 65 years.

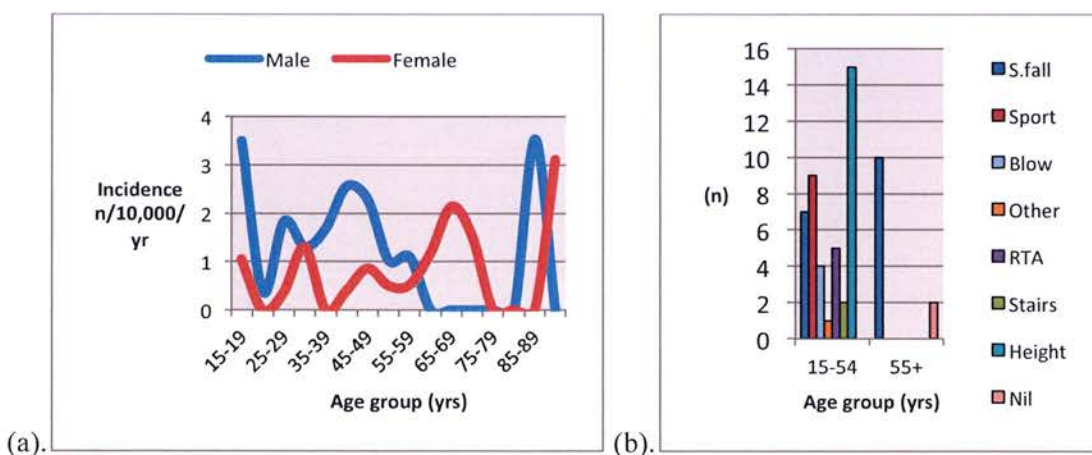


Figure 3.57 (a) The age- and gender-related incidence of fractures of the distal tibia occurring in Edinburgh adults. (b) The modes of injury responsible for distal tibial fractures, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

All distal tibial fractures occurring in patients aged 55 years or older were caused by low energy trauma, including two fractures through metastatic lesions. In younger adults, 20 (46.5%) fractures resulted from RTAs and falls from a height. A further nine (20.9%) injuries were sports-related. Women were more likely to sustain AO type A extra-articular fractures as a result of low energy trauma (Table 3.55). Overall, intra-articular type B and C fractures were more common, and they affected a predominantly young male patient group with 53.3% resulting from high energy trauma. The frequency of open fractures was low (1.8%), and the only open injury occurred in association with a type C fracture.

	AO type			p-value
	A	B	C	
Fractures (n, %)	23 (43.4)	18 (34.0)	12 (22.6)	-
Gender ratio (M:F, %)	43:57	83:17	83:17	$p=0.010^*$
Median age (yrs, IQR)	49 (30-69)	30.5 (27-43.5)	37.5 (24-49.5)	$p=0.071^k$
Mode of injury (n, %)				$p=0.030^*$
Simple fall	11 (47.8)	2 (11.1)	2 (16.7)	
Sports-related	3 (13.0)	5 (27.8)	1 (8.3)	
Direct blow	3 (13.0)	1 (5.6)	0	
Other	0	1 (5.6)	0	
RTA	3 (13.0)	1 (5.6)	1 (8.3)	
Fall down stairs	0	1 (5.6)	1 (8.3)	
Fall from a height	1 (4.3)	7 (38.9)	7 (58.3)	
Nil / spontaneous	2 (8.7)	0	0	
% multiple fractures	8.7	0	16.7	$p=0.230^*$
% open fractures	0	0	8.3	$p=0.175^*$

Table 3.55 The number and frequency of distal tibial fractures, occurring in Edinburgh adults, according to AO fracture type. The age- and gender-related distribution of patients affected is given, as well as the proportion of open injuries and associated fractures encountered. *Chi square test. ^kKW test. (RTA = road traffic accident).

Ankle fractures

A fracture of the ankle refers (in most instances) to osseous injury of the malleolar region of the distal tibia and / or fibula. However, a supra-syndesmotomic fracture of the fibula with associated medial soft tissue disruption is still considered an 'ankle fracture'. Marginal fractures of the tibial plafond may occur in addition to malleolar injury. The main diagnostic distinction between ankle and distal tibial fractures relates to the fracture morphology. Ankle fracture patterns result from indirect rotational forces acting upon the talus within the ankle mortise. However, a proportion of ankle fractures occur in the absence of rotation, from pure adduction or abduction forces.

Ankle fractures are commonly encountered in orthopaedic practice. The present series contained 631 fractures sustained by 627 patients. There were three patients with bilateral

fractures and one with a contralateral ankle injury many months after the index fracture. The median age of all patients was 50 years (IQR, 31-64 yrs), with a range from 15 to 98 years. In contrast to all previously published literature reporting ankle fracture incidence in all adult age groups, women (53.6%) were affected more commonly than men (46.4%). The median age of affected women was 59 years (IQR, 44-69 yrs) and they represented a significantly older group than men (median age 40 years, IQR 26-54 yrs), ($p < 0.001$, MWU test). Ankle fractures accounted for 24.6% of lower limb fractures and 9.2% of all adult fractures.

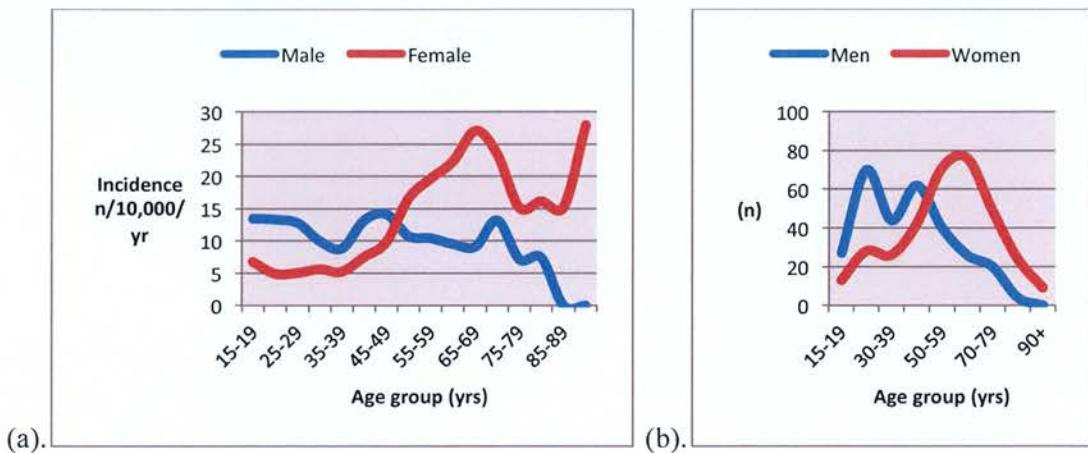


Figure 3.58 (a) The age- and gender-related *incidence* of ankle fractures occurring in Edinburgh adults. (b) The actual *number* of ankle fractures encountered, and presented according to patient age and gender.

The overall incidence was 11.6 /10,000/yr (95% CI, 10.7-12.5), with a similar incidence in women (11.8/10,000/yr) and men (11.3/10,000/yr). A unimodal fracture distribution was seen in female patients, with a peak in those aged 60 to 69 years (Fig. 3.58, above). The incidence in men was higher than in women until the age of 50 years, when a marked post-menopausal rise was seen. The curve is type A as described by Court-Brown and Caesar¹³².

The overall incidence was greater in the present series than that reported in Edinburgh adults in 2000¹³², but was less than that reported in an epidemiological survey of 1,500 ankle fractures in Edinburgh between 1988 and 1990 (12.2/10,000/yr)²⁵⁴. All of the Edinburgh studies have obtained fracture data from an established trauma database which has been classified and collected by orthopaedic clinicians. Since 1988 there has been a gentle shift in gender-related incidence, such that overall incidence in women is now higher than that of men. However, the unimodal younger male and older female distribution pattern has remained unchanged (Fig. 3.59, next page).

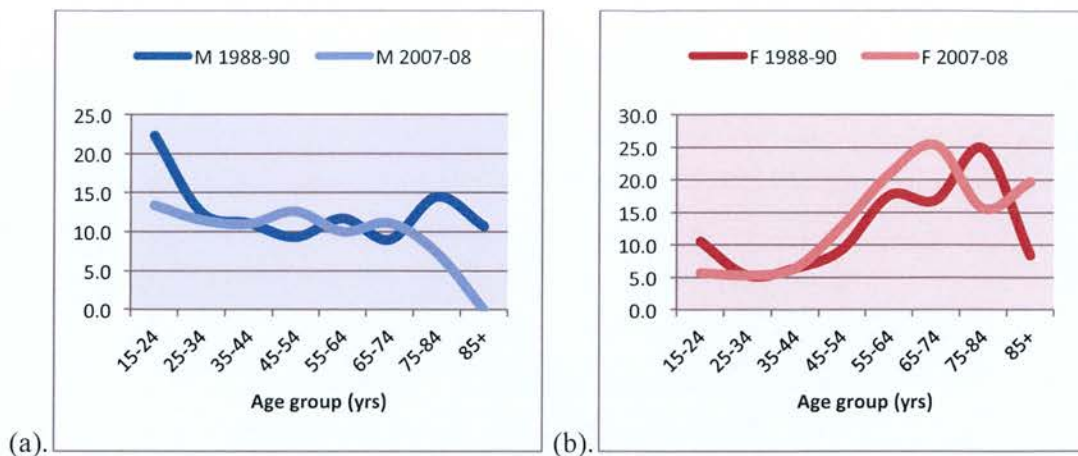


Figure 3.59 The age-related incidence (n/10,000/yr) of ankle fractures occurring in men (a) and women (b) in Edinburgh, between 1988 and 1990, and in the present series (2007-08).

A simple fall from a standing height caused 394 (62.4%) ankle fractures in the current study, and two-thirds of those affected were women. There were 94 (14.9%) sports-related fractures, of which 83.0% occurred in men. Falling down stairs caused 47 (7.4%) fractures and these injuries were more common in female patients (60% vs. 40%). The frequency of high energy trauma was low (8.0%), but it affected a predominantly young male population. Road traffic accidents accounted for 24 ankle fractures; 75% of these affected cyclists and motorcyclists, only one occurred in a vehicle occupant. Twenty fractures resulted from a fall from a height. As illustrated in Figure 3.60, sports-related injury and high energy trauma occurred more frequently in younger adult age groups. With increasing age, a simple fall from a standing height became the predominant cause of ankle fractures.

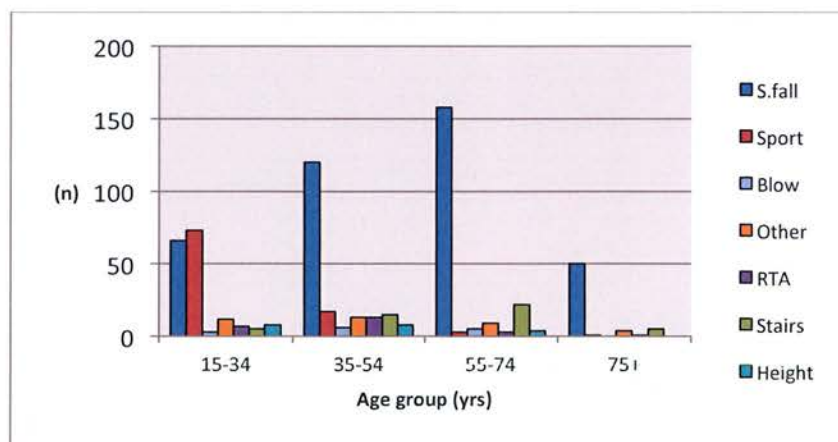


Figure 3.60 The distribution of the modes of injury involved in causing ankle fractures in Edinburgh adults, and presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from a height).

Ankle fractures can be classified in a number of ways. The most straightforward system was first described by the English surgeon Sir Percivall Pott in 1769²⁵⁵. He described ankle fractures as unimalleolar (affecting the lateral or medial malleolus) or bimalleolar (affecting both). The term ‘trimalleolar’ denotes additional involvement of the posterior border of the tibial plafond. The position of the lateral malleolar fracture in relation to the inferior tibio-fibular syndesmosis allows the fracture to be termed infra-syndesmotiC, supra-syndesmotiC or occurring at the level of the syndesmosis. This syndesmotiC description formed the basis of the classification system formulated by Danis⁶⁷, and modified by Weber⁶⁸ (Fig. 3.61). The AO and OTA comprehensive classification systems for ankle fractures are based on this system (see the Appendix).

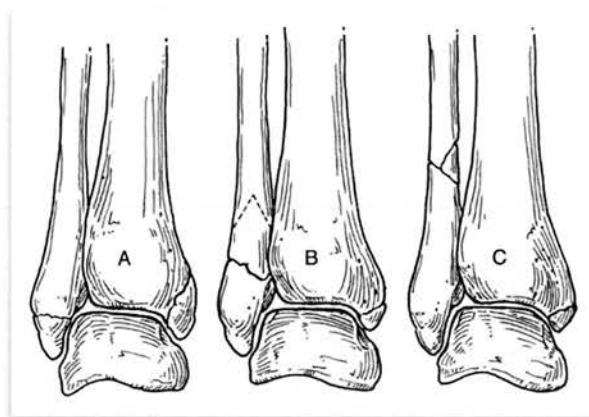


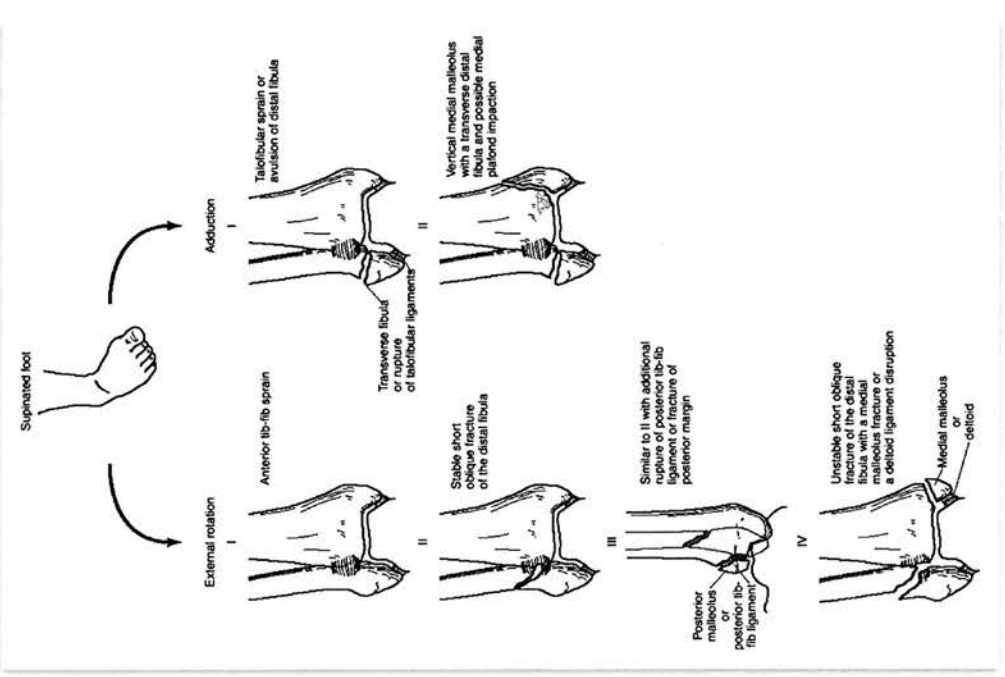
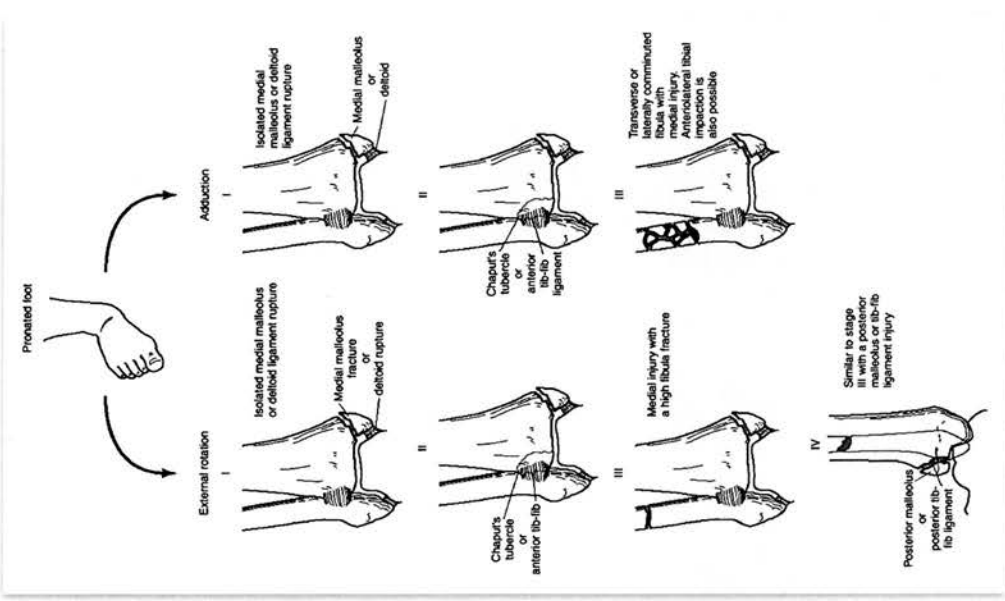
Figure 3.61 The classification of fractures of the lateral malleolus of the ankle, according to the system of Weber⁶⁸ (and Danis⁶⁷). Type A are located below, type B at the level of, and type C above, the syndesmosis.

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The Lauge-Hansen classification system utilises plain radiographs of the ankle. It groups fractures according to the most likely rotational mechanism causing the pattern of fracture(s) identified. The system was developed from a cadaveric experiment where the tibia was fixed and a rotational deforming force was applied to the foot⁶⁶. The first part of the system describes the position of the foot at the time of injury, while the second describes the direction of the applied force. For a given foot position and deforming force, the authors reported a consistently reproducible pattern of osseous and ligamentous injury (Fig. 3.63).

Figure 3.62 (next page) The mechanistic classification of ankle fracture patterns, according to the Lauge-Hansen system⁶⁶. *Left*: supination external rotation (SER) stage I to IV, supination adduction (SA) stage I and II. *Right*: pronation external rotation (PER) stage I to IV, pronation abduction (PA) stage I to III.

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The original AO, and OTA, systems (based upon Weber and Danis), and the mechanistic system proposed by Lauge-Hansen, have been found to have moderate to good interobserver reliability^{256, 257}. Reliability decreased with more detailed subclassification, and this was particularly true for the staging of Lauge-Hansen supination adduction and supination external rotation injuries²⁵⁷.

Daly *et al* reported that 27% of ankles fractures recorded in Rochester were AO type A, 41% were type B and 9% were type C injuries²⁵⁸. In the Edinburgh study AO type B fractures were also the most common (52%), followed by type A infra-syndesmotic fractures (38%). Two-thirds of these malleolar fractures were unimalleolar, 13% were bimalleolar and 7% were trimalleolar. Type C supra-syndesmotic fractures accounted for 10%²⁵⁴.

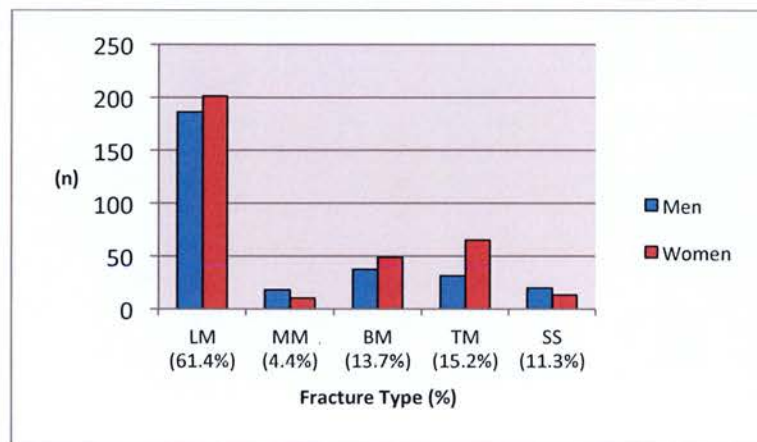


Figure 3.63 The number of men and women in Edinburgh sustaining fractures of the ankle, arranged according to the type of fracture suffered. The relative proportions of lateral malleolar (*LM*), medial malleolar (*MM*), bimalleolar (*BM*), trimalleolar (*TM*) and supra-syndesmotic (*SS*) injuries are also shown. Of note, 38 *BM* and *TM* fractures involved a *SS* fibular injury, and have been included in more than one group.

Figure 3.63, above, shows the distribution of ankle fractures in the present series. Of note, one ankle fracture could not be classified due to unavailable radiographs. Unimalleolar fractures of the lateral malleolus were most common. They affected men and women in approximately equal proportions, with a median patient age of 49 years (IQR, 30-62 yrs). Fractures of the medial malleolus (age 35.5 years, IQR 20-57 yrs) and isolated supra-syndesmotic ankle fractures (age 41 years, IQR 23.5-57 yrs) affected a younger patient group where men outnumbered women. In contrast, the inherently unstable bimalleolar (age 56 years, IQR 40-71 yrs) and trimalleolar (age 55 years, IQR 42-67 yrs) ankle fractures occurred in older patients. Trimalleolar fractures in female patients were twice as common as in male

patients. The distribution of patient age between groups was significantly different ($p < 0.001$, KW test).

Type A		Type B		Type C	
Subtype	n (%)	Subtype	n (%)	Subtype	n (%)
A1.1	-*	B1.1	171	C1.1	17
A1.2	88	B1.2	15	C1.2	13
A1.3	51	B1.3	12	C1.3	7
A2.1	28	B2.1	50	C2.1	12
A2.2	3	B2.2	43	C2.2	7
A2.3	9	B2.3	6	C2.3	5
A3.1	0	B3.1	23	C3.1	4
A3.2	0	B3.2	44	C3.2	1
A3.3	4	B3.3	12	C3.3	5
	183 (29.0)		376 (59.7)		71 (11.3)

Table 3.56 The number and frequency of ankle fractures, occurring in Edinburgh adults, arranged according to AO fracture type. The number of fractures in each of the AO fracture groups and subtypes is also given. *Subtype A1.1 was not included as it represents lateral ligament injury only.

The distribution of ankle fractures according to the AO classification system is shown in Table 3.56, above. The commonest subtype encountered was the B1.1 isolated fracture of the lateral malleolus at the level of the syndesmosis, representing 27.1% of all adult ankle fractures. The median patient age was 47 years, and men accounted for 55%. The A1.2 avulsion fracture of the tip of the lateral malleolus (14.0%) affected patients with a median age of 51 years, and two-thirds were women. Further analysis of the three AO fracture types is shown in Table 3.57 (next page).

Men represented a consistently younger patient group than women across all AO fracture types. In type C supra-syndesmotic fractures there was a trend towards a larger proportion of male patients, and the frequency of injuries sustained by relatively high energy trauma (RTAs, falls from a height, sporting activity) approached 30%. More than half of all type C fractures involved two or three malleoli. The age and gender distribution of type A and B fractures was similar, although the frequency of bimalleolar and trimalleolar injuries in type A was low. The rate of open fractures was 0.8%. Figure 3.64 (next page) illustrates the differences between the genders with relation to the mode of injury and fracture pattern encountered.

	Type A	Type B	Type C	p-value
Gender ratio (M:F, %)	42:58	47:53	58:42	$p=0.066^*$
Incidence (n/10,000/yr, 95% CIs)	3.4 (2.9-3.9)	6.9 (6.2-7.6)	1.3 (1.0-1.6)	-
Median age (yrs, IQR)	51 (31-62)	50.5 (35-66)	42 (27-57)	$p=0.047^k$
Men	37 (24-53.5)	43 (27-56)	34 (23.5-50.5)	$p=0.143^k$
Women	59 (42-71)	60 (45-69)	55 (33-67)	$p=0.306^k$
Mode of injury (n, %)				
Simple fall	19 (65.0)	240 (63.8)	34 (47.9)	$p=0.020^*$
Sports-related	24 (13.1)	55 (14.6)	15 (21.1)	
Direct blow	4 (2.2)	5 (1.3)	5 (7.0)	
Other	10 (5.5)	23 (6.1)	5 (7.0)	
RTA	10 (5.5)	9 (2.4)	5 (7.0)	
Fall down stairs	8 (4.4)	33 (8.8)	6 (8.5)	
Fall from a height	8 (4.4)	11 (2.9)	1 (1.4)	
Open #s (n, %)	0	5 (1.3)	0	$p=0.182^*$
Multiple #s (n, %)	18 (9.8)	8 (2.1)	4 (5.6)	$p<0.001^*$
Bi / Trimalleolar (n, %)	16 (8.7)	128 (34.0)	38 (53.5)	$p<0.001^*$

Table 3.57 The incidence and age- and gender-related patient details for fractures of the ankle, occurring in Edinburgh adults, according to AO fracture type. The modes of injury involved are also shown, as well as the proportion of open fractures and bi- or tri-malleolar injuries. *Chi square test. ^kK W test. (RTA = road traffic accident; #s = fractures).

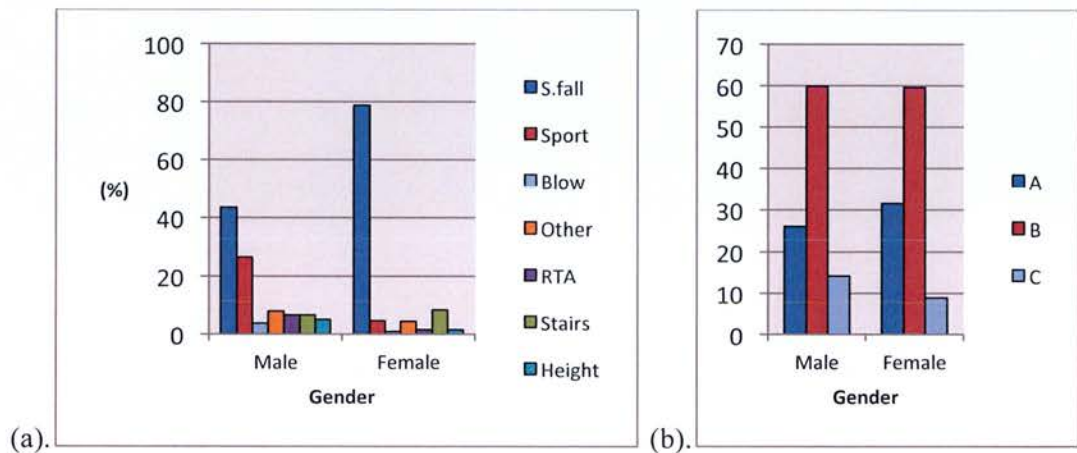


Figure 3.64 (a) The distribution of the modes of injury responsible for ankle fractures in Edinburgh adults, and presented according to patient gender. (b) The gender-related distribution of AO ankle fracture types. All values are expressed as proportions (%) of patients in male and female groups. (Blow = direct blow; RTA = road traffic accident; Stairs = fall down stairs; Height = fall from a height).

3.16 Fractures in the foot and tarsus

Hindfoot fractures

Fractures of the talus and calcaneus are encountered relatively infrequently in orthopaedic practice, but may be associated with serious complications. Due to the precarious blood supply of the talar body, talar neck fractures may be associated with rates of secondary osteonecrosis ranging from 40% to nearly 100% depending on the degree of fracture displacement^{69, 259}. Residual incongruity of the ankle or subtalar joints can predispose to secondary osteoarthritis and persistent pain. The results of one series of intra-articular calcaneal fractures demonstrated significant and long term functional impairment in a large proportion of patients⁷⁰.

	Calcaneus	Talus	p-value
Fractures (n, %)	55 (62.5)	33 (37.5)	-
Gender ratio (M:F, %)	77:23	61:39	$p=0.178^*$
Incidence (n/10,000/yr, 95% CI)	1.0 (0.8-1.3)	0.6 (0.4-0.8)	-
Median age (yrs, IQR)	36.5 (23-51.5)	33 (23-44.5)	$p=0.498^{**}$
Men	30 (22.5-44.5)	32.5 (23-44)	$p=0.782^{**}$
Women	55 (44-65)	36 (23.5-49.5)	$p=0.026^{**}$
Mode of injury (n, %)			
Simple fall	9 (16.4)	10 (30.3)	$p=0.002^*$
Sports-related	2 (3.6)	7 (21.2)	
Direct blow	2 (3.6)	2 (6.1)	
Other	1 (1.8)	0	
RTA	2 (3.6)	5 (15.2)	
Fall down stairs	5 (9.1)	3 (9.1)	
Falls from a height	34 (61.8)	6 (18.2)	
Open #s (n, %)	1 (1.8)	0	$p=1^*$
Ipsilateral foot #s (n, %)	4 (7.3)	5 (15.2)	$p=0.414^*$
Multiple #s (n, %)	22 (40.0)	7 (21.2)	$p=0.114^*$

Table 3.58 The number, frequency and incidence of hindfoot fractures occurring in Edinburgh adults. The age- and gender-related distribution of affected patients is also shown, as well as the modes of injury involved. The proportions of open injuries and patients with additional fractures of the ipsilateral foot are also given. *Chi square test. **MWU test. (RTA = road traffic accident).

The majority of serious hindfoot fractures result from high energy trauma, and they often occur in patients with multiple fractures. The present series contained 88 hindfoot fractures sustained by 80 patients (Table 3.58, above). Seven patients suffered bilateral calcaneal fractures and one patient suffered a combined injury involving the talus and calcaneus. Men were more commonly affected than women. Fractures of the talus affected a universally younger patient age group, irrespective of gender. Calcaneal fractures affected young men

and older women ($p=0.002$, MWU test). High energy trauma accounted for 53.4% of hindfoot fractures.

One-third of all hindfoot fractures involved the talus. Thirty three fractures were sustained by 33 patients with a median age of 33 years (R 15-77 yrs, IQR 23-44.5 yrs). There were 20 men and 13 women, with no difference in age distribution between the genders. Talar fractures accounted for 4.9% of foot fractures, 1.3% of lower limb fractures and 0.5% of all acute fractures. The overall incidence was 0.6 /10,000/yr (95% CI, 0.4-0.8) with a higher rate in men (0.8/10,000/yr, 0.4-1.2) than in women (0.5/10,000/yr, 0.2-0.8). The resultant distribution curve shows a unimodal young male and female pattern (type C) with a small number of sporadic cases in older adults (Fig. 3.65). The majority of fractures affected patients younger than 55 years. Six fractures affecting older adults all occurred following a simple fall from standing. Two-thirds of fractures in younger adults resulted from sporting activity or high energy trauma.

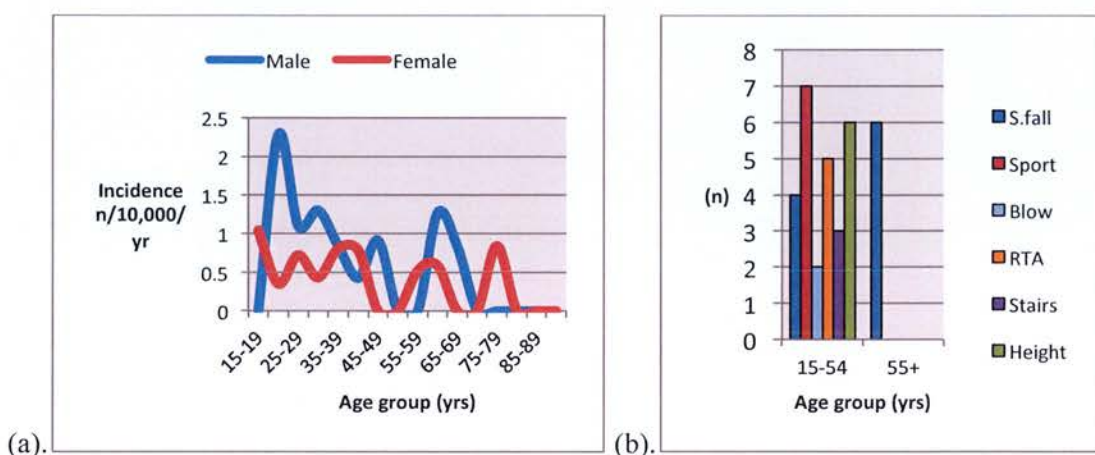


Figure 3.65 (a) The age- and gender-related incidence of fractures of the talus occurring in Edinburgh adults. (b) The modes of injury responsible for talar fractures, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

The AO classification of talar fractures describes avulsion fractures, talar process or talar head fractures (type A), neck fractures (type B) and body and dome fractures (type C)¹⁴. Type A groups include neck avulsions, lateral or posterior process fractures, and fractures of the head in the absence of neck trauma. Type B groups are determined by the presence of displacement or comminution of the neck fracture. Type C groups delineate the degree of ankle or subtalar joint involvement. The description of type B talar neck fractures is based upon the classification described by Hawkins⁶⁹ (and modified by Canale and Kelly²⁵⁹).

Hawkins originally described undisplaced fractures (type 1), displaced fractures with subtalar joint subluxation or dislocation (type 2), and displaced fractures with subtalar and tibiotalar joint dislocation (type 3). Canale and Kelly later described the talar neck fracture with associated talonavicular joint dislocation as 'type 4'.

Twenty four fractures (72.7%) were AO type A: 12 avulsion fractures of the anterior talar neck, six posterior process fractures, five lateral process fractures, and one talar head injury. One anterior avulsion fracture occurred in conjunction with a subtalar dislocation following a high energy fall from a height. The remainder accounted for the disproportionately large number of low energy fractures in the type A group ($p=0.007$, Chi square test), as illustrated in Figure 3.66.

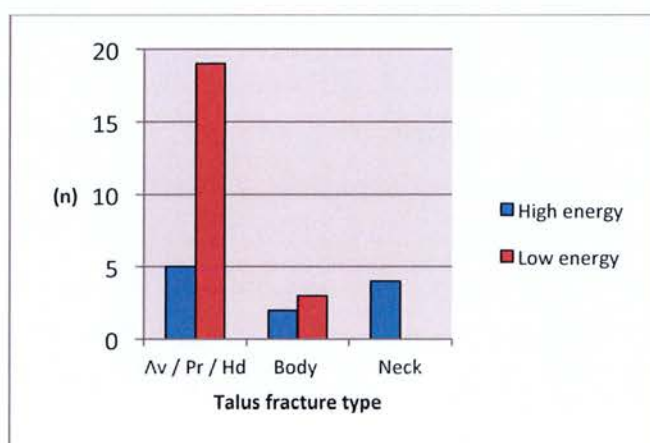


Figure 3.66 The number of high energy and low energy talar fractures sustained by Edinburgh adults, arranged according to the anatomical fracture location. The relative proportions of avulsion / process / head fractures (*Av/Pr/Hd*), body fractures, and neck fractures are shown.

Posterior process fractures can be caused by forced pronation and dorsiflexion (medial tubercle avulsion by the deltoid ligament), forced inversion (lateral tubercle avulsion by the posterior talofibular ligament) or impingement during forced plantarflexion (both tubercles). Six such injuries were identified, and were caused by sporting activity ($n=3$), a motorcycle accident ($n=1$) and falls down stairs ($n=2$). Of note, it can be notoriously difficult to identify these injuries on plain radiographs due to frequent confusion with an os trigonum. Lateral process fractures have received increasing attention in recent years due to their association with snowboarding²⁶⁰. They may be caused by avulsion or axial loading mechanisms and five such fractures were identified, (although an association with Alpine pursuits was not identified). Head fractures are very uncommon and are thought to result from axial loading

in plantarflexion. In the present series, one talar head fracture occurred as an isolated injury in a young man involved in a motorcycle accident.

Talar body (15.2%) and neck (12.1%) fractures resulted from high energy accidents. Body fractures occur as the result of axial loading between the tibial plafond and the calcaneus. In this series, two were sustained following falls from a height. Three fractures resulted from lower energy trauma, although a fall down stairs (n=1), a fall following a BMX jump (n=1) and a fall from a horse (n=1) are still likely to involve significant energy transfer. Four fractures involved the talar neck (three Hawkins type 1; one Hawkins type 2). Initially recognised as resulting from forced dorsiflexion injuries (the aviator's astragalus²⁶¹), biomechanical research has suggested they result from axial loading of the plantar flexed foot²⁶². All four fractures involved high energy transfer (three RTAs, one fall from a height).

Two-thirds of hindfoot fractures involved the calcaneus. In addition to the previously described patient who sustained a combined talar / calcaneal injury, 40 patients sustained a unilateral fracture and seven suffered bilateral fractures. These injuries occurred in young men (n=37) and older women (n=11), (Table 3.58). Calcaneal fractures accounted for 8.1% of foot fractures, 2.1% of lower limb fractures and 0.8% of all acute fractures. The overall incidence was 1.0/10,000/yr (95% CI, 0.8-1.3) with a significantly higher rate seen in men (1.7/10,000/yr, 1.2-2.2) than in women (0.4/10,000/yr, 0.2-0.7). The unimodal young male distribution and low incidence seen in women indicates a type B curve (Fig. 3.67).

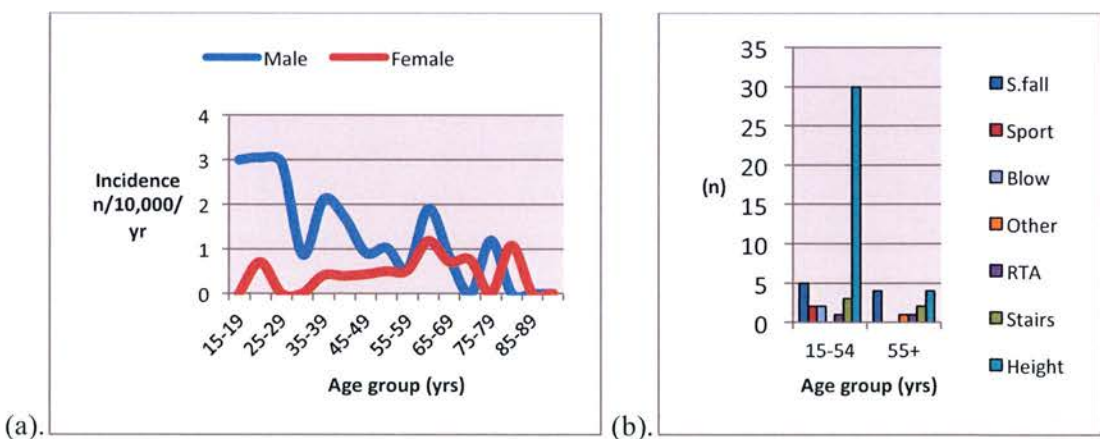


Figure 3.67 (a) The age- and gender-related incidence of fractures of the calcaneus occurring in Edinburgh adults. (b) The modes of injury responsible for calcaneal fractures, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

The literature suggests 90% of calcaneal fractures occur in men aged between 21 and 45 years, and that high energy trauma is responsible for the majority of injuries^{263, 264}. These data are derived from retrospective reviews of operatively treated injuries, and may therefore be skewed towards the more severe end of the injury spectrum. In the present series, 58.5% of injuries occurred in men aged less than 45 years; the frequency of high energy injury within this group was 71.4%. By far the commonest cause was a fall from a height (61.8%). Notably, all bilateral calcaneal fractures resulted from high energy trauma. In female patients and older men, the frequency of high energy trauma was slightly lower at 50%. Table 3.64 shows a significant number of calcaneal fractures were associated with fractures elsewhere. Aside from contralateral calcaneal injuries, associated fractures followed the typical pattern representative of high energy transfer sustained by axial loading of the lower limbs and axial skeleton. They included those of the midfoot and forefoot (n=6), ankle (n=4), tibial plateau (n=1), femoral shaft (n=1), proximal femur (n=1) and pelvic ring (n=2). One proximal humerus injury was also encountered.

The original AO system, since adopted by the OTA¹⁴, classifies calcaneal fractures by drawing upon the work of many authors. Type A fractures are avulsion injuries or fractures of the various tuberosities and processes. Type B fractures affect the body but spare the posterior facet. Group B3 fractures involve the calcaneocuboid joint. Type C fractures are posterior facet (intra-articular) fractures. Relatively little information exists on the overall distribution of calcaneal fractures. In 1953, Warrick and Bremner classified 300 calcaneal fractures²⁶⁵. Interpretation of their own (now outdated) system of classification reveals that 25% were avulsions or process fractures, 30% were body fractures sparing the posterior facet, and the remaining 45% involved the posterior facet. Seventy nine percent of their posterior facet fractures were displaced.

Around the same time, Essex-Lopresti published his influential work describing the proposed mechanism by which calcaneal fractures occur and propagate⁷⁰. The primary fracture line is produced laterally as the talus is driven down into the calcaneus with the subtalar joint everted (Fig. 3.68, next page). The lateral wall of the calcaneus is split in two at the crucial angle of Gissane. The force extends medially to the sustentaculum and anteriorly to the anterior process or calcaneocuboid joint. Continued force causes a second fracture line to occur. Depending on the direction of this force, the fracture will continue and exit behind or into the posterior facet (joint depression fracture) or inferior to the tuberosity (tongue type fracture).

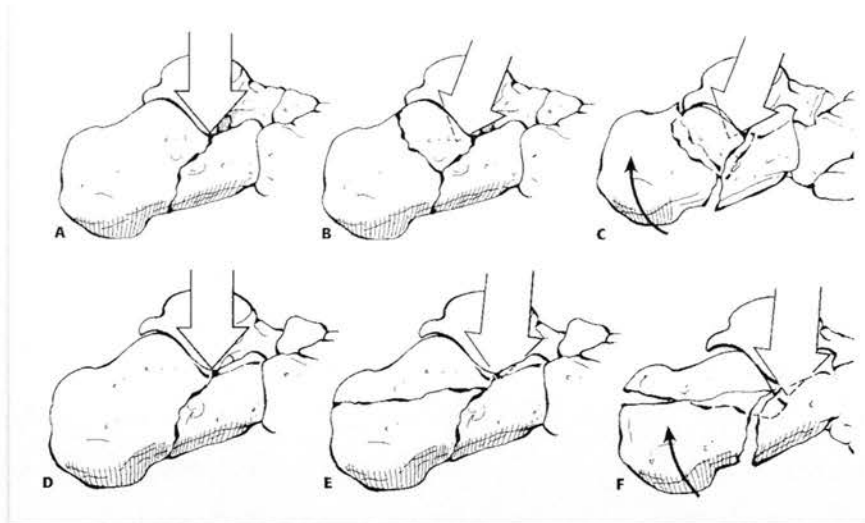


Figure 3.68 The mechanism of injury producing a joint depression or tongue type calcaneal fracture, according to Essex-Lopresti⁷⁰. The primary fracture line begins laterally at the crucial angle of Gissane (*A and D*) as the talus is driven down into the calcaneus with the subtalar joint everted. The lateral wall of the calcaneus is split in two and the force extends medially to the sustentaculum and anteriorly to the anterior process or calcaneocuboid joint. Continued force causes a second fracture line to occur. Depending on the direction of this force, the fracture will continue and exit behind or into the posterior facet (joint depression fracture, *B and C*) or inferior to the tuberosity (tongue type fracture, *E and F*). (Reproduced with permission from Lippincott Williams & Wilkins publishers).

The advent of CT imaging improved the understanding of calcaneal fractures. It allowed for more detailed analysis of intra-articular fractures and encouraged the development of new systems of classification. The most useful and widely used CT classification system is that of Sanders *et al*⁷¹. It relies upon a coronal plane CT image of the posterior facet and divides the facet into four potential parts (Fig. 3.69, next page). All undisplaced or minimally displaced (<2mm) articular fractures are termed type 1. Displaced fractures dividing the posterior facet into two, three, or four or more parts are termed types 2, 3 and 4 respectively. The additional use of the letters A, B and C refers to the position of the fractures lines from lateral to medial.

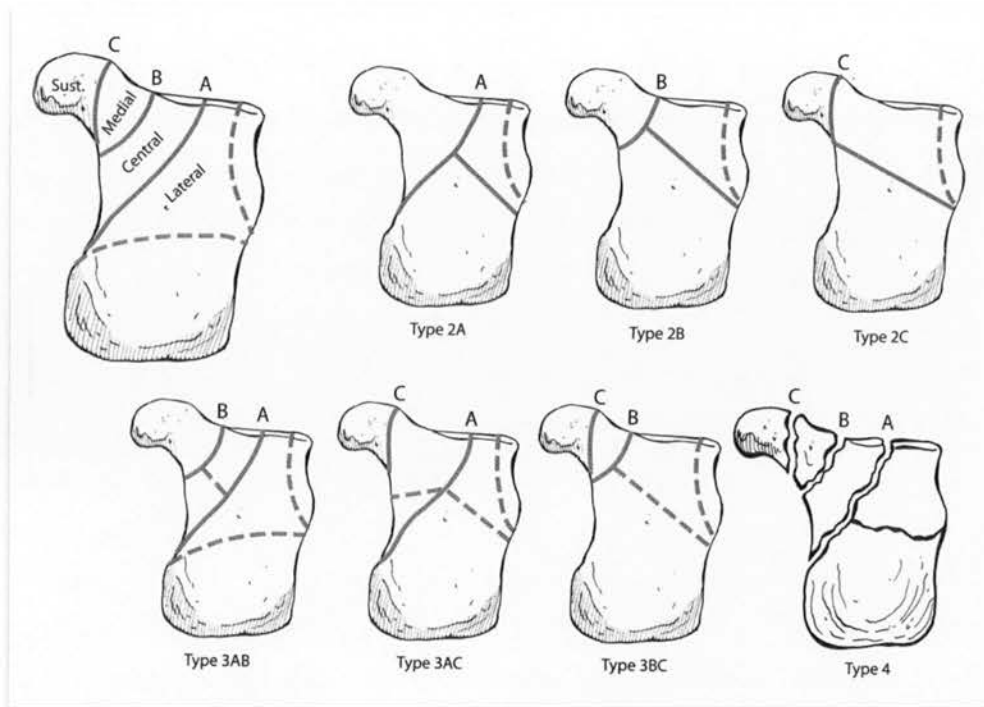


Figure 3.69 The computed tomography (CT) scan classification of intra-articular calcaneal fractures, according to Sanders *et al*⁷¹. Using the coronal plane CT image of the posterior facet, the facet is divided into four potential parts. All undisplaced or minimally displaced articular fractures are termed type 1. Displaced fractures dividing the posterior facet into two, three, or four or more parts are termed types 2, 3 and 4 respectively. The additional use of the letters A, B and C refers to the position of the fractures lines from lateral to medial. (Reproduced with permission from Lippincott Williams & Wilkins publishers).

The distribution of broad fracture types encountered in the present series is shown in Table 3.59. In keeping with all other described fracture types in this study, calcaneal fractures have been diagnosed from plain radiographs with additional information provided by CT in 39 of the 55 fractures.

	Avulsion / process	Body	Posterior facet	p-value
Patients (n, %)	7 (14.5)	26 (54.2)	15 (31.3)	-
Fractures (n, %)	7 (12.7)	31 (56.4)	17 (30.9)	-
Gender ratio (M:F, %)	71:29	73:27	87:13	$p=0.565^*$
Median age (yrs, IQR)	50 (22-60)	32.5 (23-47)	37 (27-50)	$p=0.565^k$
Falls from a height (n, %)	2 (28.6)	20 (64.5)	12 (70.6)	$p=0.431^*$

Table 3.59 The number and frequency of calcaneal fractures, occurring in Edinburgh adults, arranged according to the anatomical fracture location. The age- and gender-related distribution of affected patients is given, as well as the proportion of injuries sustained by falling from a height. *Chi square test. ^kK W test.

Seven fractures were AO type A. Five anterior process avulsion fractures were sustained by lower energy injury modes. These avulsions are reported to result from forced inversion and plantarflexion injuries, which increase tension in the bifurcate ligament²⁶⁶. Two calcaneal tuberosity fractures resulted from falls from a height. Thirty one type B extra-articular body fractures occurred and five patients suffered bilateral injuries. Three fractures were 73-B3 injuries involving the calcaneocuboid joint. Of the remaining 28 fractures, Bohler's angle was positive in 27 (96.4%) and neutral in one (3.6%). Extra-articular fractures and those involving the posterior facet affected a similar patient group. This is to be expected as the mechanism of injury follows the same pattern. Seventeen fractures were type C, involving the posterior facet. Patient age increased with increasing fracture severity, as measured by the Sanders classification, although this trend was not statistically significant. Sanders type 2 fractures affected eight patients with a mean age of 36.5 years, and 25% had suffered multiple fractures. Sanders 3 injuries occurred in six patients with a mean age of 42 years, and 67% had associated fractures. There were three Sanders 4 fractures (mean age 44 years) with the frequency of associated fractures being 67%.

Midfoot and forefoot fractures

The midfoot is that part of the foot distal to Chopart's joint line (the talonavicular and calcaneocuboid joints) but proximal to Lisfranc's joint (the tarsometatarsal joints). It is composed of the navicular, cuboid and cuneiforms (medial, middle and lateral). The midfoot acts as a stable bridge between the hindfoot and forefoot and owes its stability to the presence of numerous strong plantar ligaments. As with hand trauma, isolated fractures are the usual result of midfoot and forefoot trauma. However, with increasing levels of violence and higher energy transfer, midfoot and forefoot fractures can involve significant injury to adjacent osseous and soft tissue structures.

Injury to Lisfranc's tarsometatarsal joint constitutes a spectrum from stable ligamentous sprains to grossly unstable fracture dislocations. A recent review on the subject has suggested that up to 20% of injuries may go initially unnoticed²⁶⁷. Injury may be caused by direct loading of the dorsum of the midfoot, or more commonly by indirect longitudinal loading of the plantarflexed foot²⁶⁸. The literature suggests that common modes of injury include falls from height, RTAs and sports-related trauma²⁶⁹, although both high and low energy transfer may be involved²⁶⁸.

The forefoot includes the five metatarsals, phalanges and sesamoids. It provides a broad plantar surface for load distribution during the normal gait cycle. It is more mobile than the midfoot, allowing some degree of forefoot conformity and pressure distribution when walking on uneven surfaces. Metatarsal and phalangeal fractures are common injuries. They result from a direct blow to the forefoot, or more commonly from indirect twisting forces. Avulsion fractures of the fifth metatarsal base are common, while sesamoid fractures are rarely encountered.

A total of 590 midfoot and forefoot fractures affected 554 patients. They accounted for 87.0% of foot fractures, 23.0% of lower limb fractures and 8.6% of all adult fractures. The frequency of open fractures was 3.4%. The median age of patients affected was 40 years (R 15-95 yrs, IQR 26-57 yrs). There were 324 women (58.5%) with a median age of 48 years (IQR, 31-61 yrs). The 230 men (41.5%) with a median age of 32 years (IQR, 22-48.5 yrs) represented a significantly younger cohort ($p < 0.001$, MWU test). The overall incidence was 10.8/10,000/yr (95% CI, 10.0-11.7) and was higher in women (11.9/10,000/yr, 95% CI 10.7-13.2) than in men (9.6/10,000/yr, 95% CI 8.5-10.9). The resultant fracture distribution curve is type D, with a unimodal younger male and bimodal female distribution (Fig. 3.70).

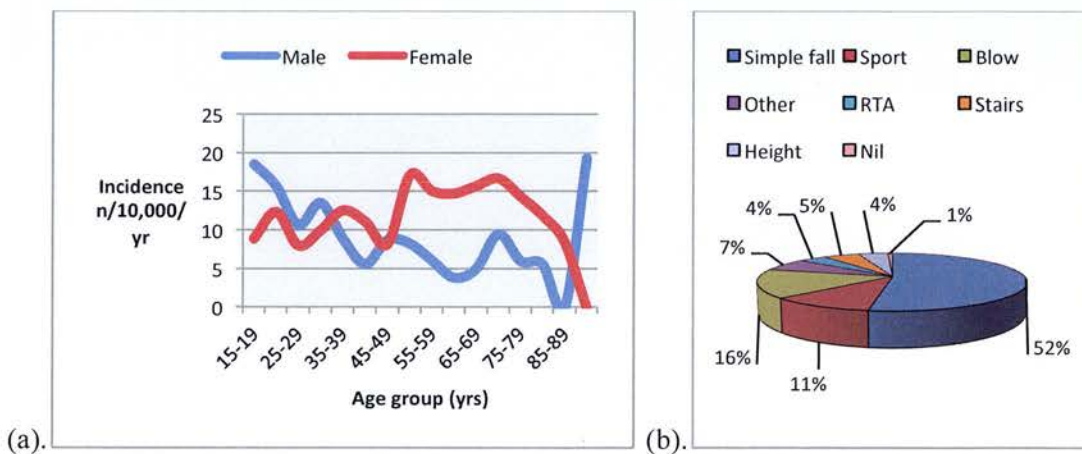


Figure 3.70 (a) The age- and gender-related incidence of midfoot and forefoot fractures occurring in Edinburgh adults. (b) The distribution of modes of injury responsible for midfoot and forefoot fractures. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

For the purposes of analysis, multiple fractures in the midfoot and forefoot were defined as a 'combination' injury. The distribution of midfoot and forefoot fractures is shown in Table 3.60 (next page). Only one sesamoid fracture was identified over the one-year study period, occurring in a 21 year old man and sustained whilst playing football.

	Midfoot	Metatarsals	Phalanges	Combination	p-value
Fractures (n, %)	23 (3.9)	348 (59.0)	111 (19.0)	107 (18.1)	-
Gender ratio (M:F, %)	39:61	36:64	56:44	47:53	p=0.002*
Median age (yrs)	39 (24-58)	43 (25-59)	33 (22-46)	48.5 (33-61)	p<0.001 ^k
Men	36 (20-57.5)	29 (21-45)	31.5 (22-47)	46 (30-54)	p=0.010 ^k
Women	39.5 (25-62.5)	51 (34-63)	33 (22-44.5)	54.5 (36.5-68)	p<0.001 ^k
Mode of injury					
Simple fall	12 (52.2)	240 (69.0)	13 (11.7)	44 (41.1)	p<0.001*
Sports-related	2 (8.7)	43 (12.4)	14 (12.6)	3 (2.8)	
Direct blow	3 (13.0)	18 (5.2)	56 (50.5)	17 (15.9)	
Other	0	23 (6.6)	14 (12.6)	4 (3.7)	
RTA	1 (4.3)	3 (0.9)	3 (2.7)	17 (15.9)	
Fall down stairs	4 (17.4)	6 (1.7)	9 (8.1)	11 (10.3)	
Fall from height	1 (4.3)	11 (3.2)	2 (1.8)	11 (10.3)	
Nil / spontaneous	0	4 (1.1)	0	0	
Open #s (n, %)	0	0	12 (10.8)	8 (7.5)	p<0.001*
Associated non-foot #s (n, %)	2 (8.7)	8 (2.3)	3 (2.7)	12 (16.7)	p<0.001*

Table 3.60 The number and frequency of midfoot and forefoot fractures occurring in Edinburgh adults. The gender ratio and gender-related age distribution of affected patients is shown. The causative injury modes and proportions of open injuries and associated fractures is also given. *Chi square test. ^kKW test. The solitary sesamoid fracture was not included in the analysis. (RTA = road traffic accident).

Isolated fractures of the navicular (n=8), cuboid (n=11) and cuneiforms (n=4) were uncommon, and affected men and women of a similar age group. Simple falls from a standing height and falls down stairs accounted for two-thirds of fractures seen. Sangeorzan *et al*²⁷⁰ introduced a classification for navicular fractures that has been adapted to apply to all midfoot bones. The authors essentially described these injuries as avulsion fractures or body fractures, with varying degrees of adjacent joint involvement. Approximately half of all isolated midfoot fractures were simple avulsions. Combination fractures of the navicular (n=2), cuboid (n=6) and cuneiforms (n=6) occurred in nine patients and represented a very different group. The average age of this subgroup was 48 years and six of nine accidents (66.7%) involved high energy transfer.

Isolated fractures of the metatarsals were the commonest fracture type seen in the midfoot and forefoot, and were the third most common lower limb fracture seen after the proximal femur and ankle. The median age of patients affected is shown in Table 3.66. Men represented a significantly younger group than women (p<0.001, MWU test). The overall incidence was 6.4/10,000/yr (95% CI, 5.7-7.1) and was significantly higher in female patients (7.8/10,000/yr, 95% CI 6.8-8.9) than in male patients (4.8/10,000/yr, 95% CI 4.0-5.8). Peak male incidence (11.5/10,000/yr) was seen in 15 to 19 year olds, where 60.9% of

injuries occurred during sporting activity. Peak female incidence (13.1/10,000/yr) occurred in those aged 50 to 54 years when a simple fall or twisting injury caused 80.8% of fractures. The resultant fracture distribution curve is type A, displaying a unimodal younger male and unimodal older female pattern (Fig. 3.71).

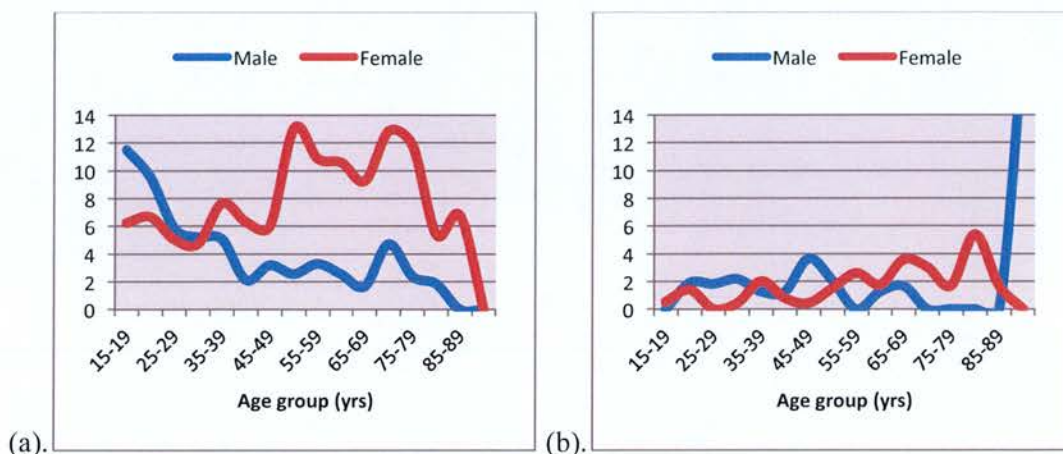


Figure 3.71 (a) The age- and gender-related incidence (n/10,000/yr) of *isolated* metatarsal fractures occurring in Edinburgh adults. (b) The age- and gender-related incidence (n/10,000/yr) of metatarsal fractures occurring as ‘*combination*’ injuries.

Eighty one metatarsal fractures presented as combination foot injuries. The distribution curve for combination metatarsal fractures is also type A (Fig. 3.71, above), although the pattern is less pronounced and skewed slightly by a high incidence in the oldest female age group. A higher proportion of men was identified (47%) when compared with isolated fractures, and the median age in men was higher at 48 years. The mode of injury responsible was also different: a simple fall from a standing height was responsible for 69.0% of isolated fractures, and this proportion increased with advancing patient age (Fig. 3.72, next page). The frequency of high energy trauma was 4.1%. In contrast, 50.8% of combination metatarsal fractures resulted from a simple fall and 28.8% were associated with high energy trauma.

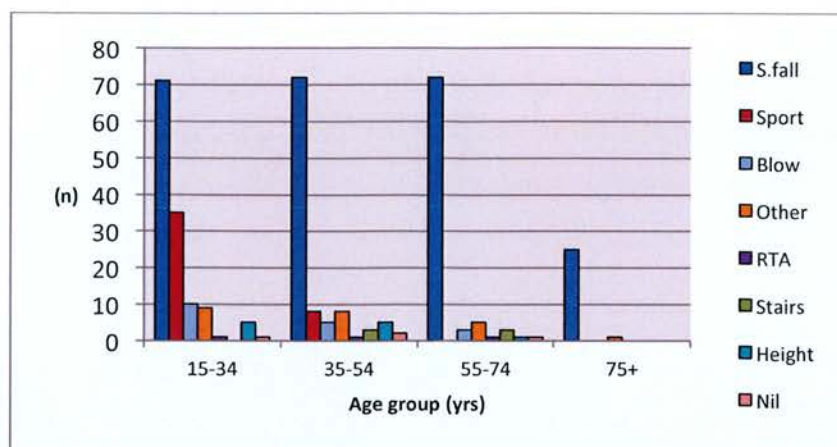


Figure 3.72 The distribution of the modes of injury involved in causing isolated metatarsal fractures in Edinburgh adults, and presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from a height).

The distribution of isolated metatarsal fractures is shown in Table 3.61. The central metatarsals are distinct from the 1st and 5th metatarsals, mainly due to their strong ligamentous interconnections and relative lack of movement. Central metatarsal fractures rarely occurred in isolation and represented a small proportion of the total (13.2%). However, the additional number of central metatarsal fractures involved in combination foot injuries is high.

	1 st ray	2 nd ray	3 rd ray	4 th ray	5 th ray	p-value
Fractures (n, %)	15 (4.3)	18 (5.2)	16 (4.6)	12 (3.4)	287 (82.5)	-
Gender ratio (M:F, %)	80:20	50:50	56:44	58:42	31:69	p<0.001*
Median age (yrs, IQR)	29 (21-38)	41 (25-58)	28 (21-49)	31 (21-63)	45 (27-60)	p=0.031 ^k
Mode of injury (%)						
Simple fall	6.7	33.3	18.8	66.7	77.4	p<0.001*
Sports-related	40.0	16.7	18.8	25.0	9.8	
RTA / Height	13.3	5.6	12.5	0	3.1	
Distribution (%)						
Head / neck	13	11	25	25	3	p<0.001*
Midshaft	13	33	63	58	28	
Base	74	56	12	17	69	
Additional number (n) and proportion (%) involved in combination fractures	5 (25.0)	42 (70.0)	46 (74.2)	40 (76.9)	8 (2.7)	-

Table 3.61 The number and frequency of isolated metatarsal fractures, occurring in Edinburgh adults, and presented according to their distribution across the five rays of the foot. The anatomic fracture location in terms of head and neck, shaft, or basal fractures is shown. Also presented, is the number of additional fractures involved in combination injuries.

Anatomically, the 2nd metatarsal base is recessed into the midfoot, increasing the osseous stability of Lisfranc's joint. For this reason, fractures of the 2nd metatarsal were more often seen at or near the base, while those of the 3rd and 4th rays occurred more frequently in the midshaft. Fractures of the larger, more mobile 1st metatarsal frequently involved the base and occurred in isolation 75% of the time. They affected a predominantly young male population and many injuries resulted from sport. Fractures of the 5th metatarsal outnumbered all other fractures in the foot, and were twice as common in women as in men. They occurred most often in isolation and resulted from a simple fall from standing or a twisting injury.

A recent review of forefoot trauma has stated that phalangeal fractures are the most common forefoot injury²⁶⁷. Results from the present series suggest metatarsal fractures are more commonly encountered in Edinburgh adults. However, it is likely that a number of phalangeal injuries will have been sustained by patients who were managed by general practitioners or chose not to seek medical advice. A total of 111 isolated phalangeal fractures were recorded and a further 12 fractures were seen in combination with other foot fractures. Isolated phalangeal fractures occurred in a younger patient group than the remaining midfoot and forefoot injuries. Fifty percent were caused by a direct blow (including crush and 'stubbing' injury mechanisms), and 10.8% were open fractures. The great toe was most commonly involved (73.0%), followed by the little toe (18.9%) and a small number of lesser toe fractures. The AO classification describes extra-articular (type A), partial articular (type B) and complete articular (type C) fractures. The distribution isolated phalangeal fractures in the present series is shown in Table 3.62.

	1 st ray	2 nd ray	3 rd ray	4 th ray	5 th ray
Fractures (n)	81	3	3	3	21
AO type (n)					
A	23	2	1	3	15
B	41	1	1	0	2
C	17	0	1	0	4

Table 3.62 The number of toe phalangeal fractures occurring in Edinburgh adults, classified by AO fracture type, and arranged according to the ray involved.

There were 107 fractures of the midfoot and forefoot that involved multiple fractures, accounting for 18.1% of fractures identified in this region. Combination fractures occurred in 72 patients, with an equal gender distribution. The median age of affected men and women was significantly older than those sustaining isolated midfoot and forefoot fractures (Table 3.60). The frequency of associated skeletal injury was also higher. The resultant

distribution curve produced by analysing *each episode* rather than *each fracture* is shown below (Fig. 3.73). The commonest mode of injury in older and younger adult groups was a simple fall or twisting injury, although a greater frequency of high energy trauma was noted in younger adults ($p=0.061$, Chi square test).

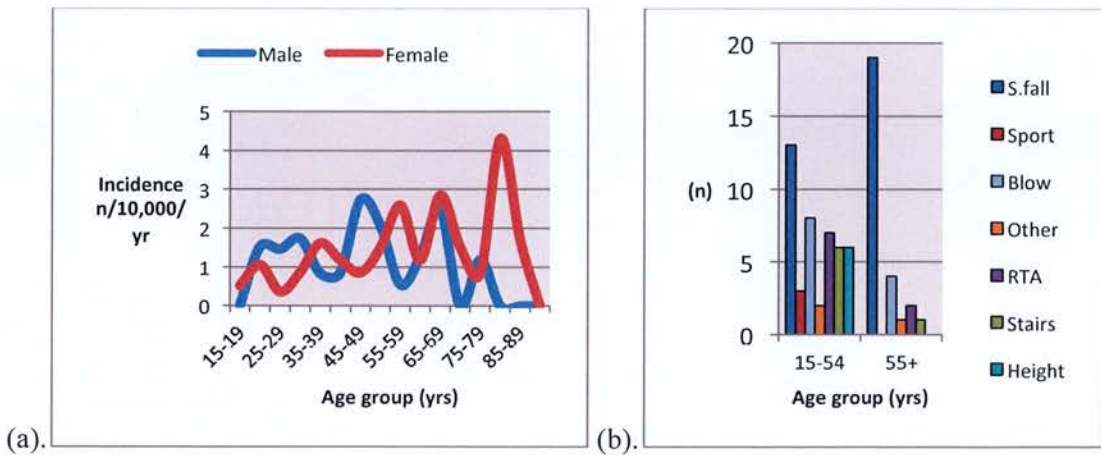


Figure 3.73 (a) The age- and gender-related incidence of *combination* fractures of the midfoot and forefoot occurring in Edinburgh adults. (b) The modes of injury responsible for combination midfoot and forefoot fractures, presented according to patient age group. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

The most common injury combination involved multiple metatarsal fractures ($n=47$ injuries, 65.3%). A small number of multiple phalangeal ($n=8$), multiple midfoot ($n=4$), midfoot plus metatarsal ($n=5$) and metatarsal plus phalangeal ($n=2$) fractures were also identified.

There were six Lisfranc tarsometatarsal fracture dislocations, occurring in four men and two women. Five cases resulted from high energy trauma (two from RTAs, two from falls from a height, and one resulting from a fall down stairs) and two were open injuries. One Lisfranc fracture dislocation resulted from a simple low energy twisting injury.

3.17 Fractures of the pelvis and acetabulum

Fractures of the pelvis

Fractures in this category included minor avulsions of the innominate bones, isolated coccygeal and sacral fractures, iliac blade fractures, fractures of the pelvic ring proper and fractures of the acetabulum.

Modern reviews on the subject of pelvic fractures concentrate on the challenging and complex management of predominantly high energy fractures patterns in younger adults²⁷¹. However, as far back as the 1970s it was noted that low energy falls caused 50% of pelvic injuries in Rochester, Minnesota, from 1968 to 1977 and elderly women appeared at greatest risk²⁷². More recent work has highlighted the growing significance of low energy pelvic fractures in older adults. Kannus *et al* have shown that the incidence of osteoporotic pelvic fractures doubled in Finland between 1970 and 1997²⁷³. Boufous *et al* reported an approximate doubling of hospital admission rates in older Australian adults with these injuries²⁷⁴.

Ragnarrson and Jacobsson analysed all pelvic fractures from 1976 to 1985 in a Swedish county²⁷⁵. They found an overall incidence of 2.0/10,000/yr. The rate in men was 1.3/10,000/yr overall and was highest (9.1/10,000/yr) in those aged more than 80 years. In women it was 2.7/10,000/yr overall and 27.7/10,000/yr in the elderly. The incidence increased exponentially in both genders after the age of 60 to 69 years. Luthje *et al* studied Finnish pelvic fractures in 1988 and also found a higher incidence in women (2.9/10,000/yr) than in men (2.0/10,000/yr)²⁷⁶.

Balogh *et al* provided a comprehensive epidemiological review of three broad categories of pelvic trauma seen in an Australian population from 2005 to 2006²⁷⁷. They excluded acetabular and isolated sacral fractures and included 138 pelvic ring fractures. Firstly, they analysed high energy fractures, defining them as those injuries sustained during RTAs, falls from a height and industrial injuries. Secondly, they analysed low energy injuries. High energy trauma was as common as low energy trauma (43% vs. 44%), but occurred in a much younger patient group (41 yrs vs. 83 yrs) with a markedly male predominance (64% vs. 20%). Finally, the authors identified a significant proportion of pelvic ring fractures (13%) occurring in patients who died prior to hospital admission. The majority of these pre-hospital deaths affected young adult victims involved in high energy trauma.

In the present series, 128 pelvic fractures were sustained by 127 patients. There was only one open injury (0.8%). One elderly female patient sustained a low energy iliac blade fracture, and then a pubic ramus fracture several months later. The median age of all affected patients was 77 years (IQR, 43-86 yrs), with a range from 15 to 99 years. This represents an increased average age of eight years when compared with a series of 99 pelvic fractures in Edinburgh adults from 2000¹³². The majority of fractures occurred in women (61.7%). In keeping with many of the previously quoted studies, men represented a younger patient group and many sustained injury from high energy trauma (Table 3.63).

	Men (n=49)	Women (n=78)	Both (n=127)	p-value
Fractures (n, %)	49 (38.3)	79 (61.7)	128 (100)	-
Fracture incidence (n/10,000/yr, 95% CIs)	1.9 (1.4-2.5)	2.7 (2.2-3.4)	2.3 (1.9-2.8)	-
Median age (yrs, IQR)	51 (32.5-77)	83 (74-90)	77 (43-86)	p<0.001**
Mode of injury (n, %)				
Simple fall	17 (34.7)	61 (78.2)	78 (61.4)	p<0.001*
Sports-related	5 (10.2)	3 (3.8)	8 (6.3)	
Direct blow	3 (6.1)	0	3 (2.4)	
Other	0	1 (1.3)	1 (0.8)	
RTA	9 (18.4)	4 (5.1)	13 (10.2)	
Fall down stairs	1 (2.0)	3 (3.8)	4 (3.1)	
Fall from a height	14 (28.6)	6 (7.7)	20 (15.7)	
% high energy injuries	61.2	16.7	33.9	p<0.001*
% with multiple fractures	38.8	25.6	30.7	p=0.172*

Table 3.63 The number and incidence of pelvic fractures occurring in male and female adults in Edinburgh. The gender-related distributions of patient age and the modes of injury involved are shown. The proportions of high energy injuries and patients suffering multiple fractures are also given. *Chi square test. **MWU test, 'p-values' have been calculated for comparisons between genders. (RTA = road traffic accident).

Pelvic fractures accounted for 1.9% of all acute adult fractures seen during the study period. The overall incidence was 2.3/10,000/yr and was slightly higher in women. The incidence was greater than that noted in the year 2000 (1.7/10,000/yr)¹³². The incidence in male patients increased dramatically after the age of 75 years, peaking at 19.3/10,000/yr in men aged 90 years or more (Fig. 3.74, next page). In women, the rate change occurred after the age of 60 years and peaked at 62.1/10,000/yr in those aged 90 years or more. This pattern of pelvic fracture distribution produced a type F unimodal older adult curve¹³².

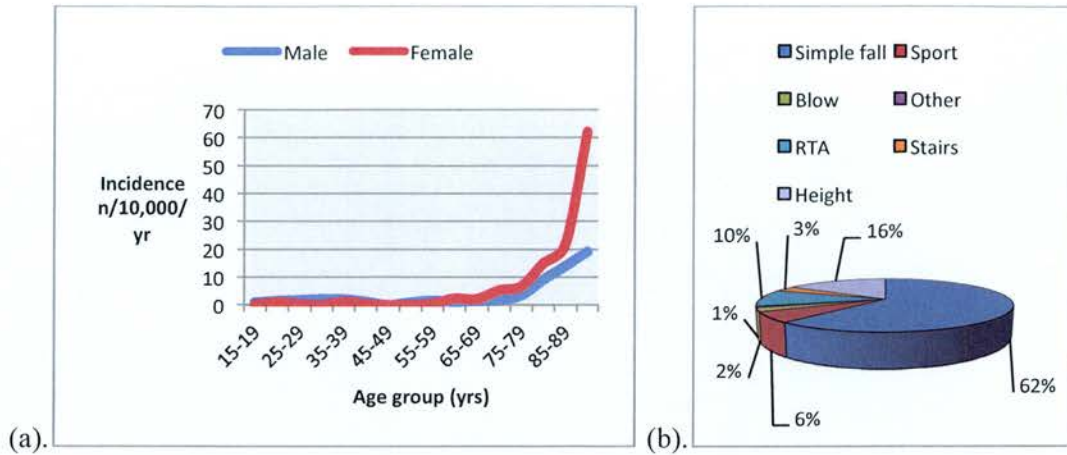


Figure 3.74 (a) The age- and gender-related incidence of pelvic and acetabular fractures occurring in Edinburgh adults. (b) The distribution of modes of injury responsible for pelvic and acetabular fractures. (*Blow* = direct blow; *RTA* = road traffic accident; *Stairs* = fall down stairs; *Height* = fall from height).

A simple fall from a standing height caused 78 (61.4%) pelvic fractures in patients with a median age of 84 years (IQR, 78-90 yrs) and a female preponderance (78.2%). Falls from height (n=20) and RTAs (n=13) caused 15.7% and 10.2% of fractures, respectively. These high energy injuries were seen in younger patients with respective median ages of 35.5 years (IQR, 26-49 yrs) and 37 years (IQR, 31.5-65 yrs). Men accounted for 70% of patients in both of these high energy groups. In total, 43 (33.9%) fractures were attributed to high energy trauma and 85 (66.1%) to low energy. The distribution curves for high and low energy pelvic fractures are shown in Fig. 3.75, (next page). The trend in high energy pelvic injury is one of a bimodal distribution in both men and women (type H curve), although men are more commonly affected. A type F unimodal older male and female pattern is observed in low energy fractures, with the rate rise occurring after 70 years in women and after 75 years in men. In contrast to Balogh *et al*²⁷⁷, who reported an approximately equal frequency of high and low energy to the pelvic ring in an Australian population, 70% of ring injuries in Edinburgh resulted from low energy trauma.

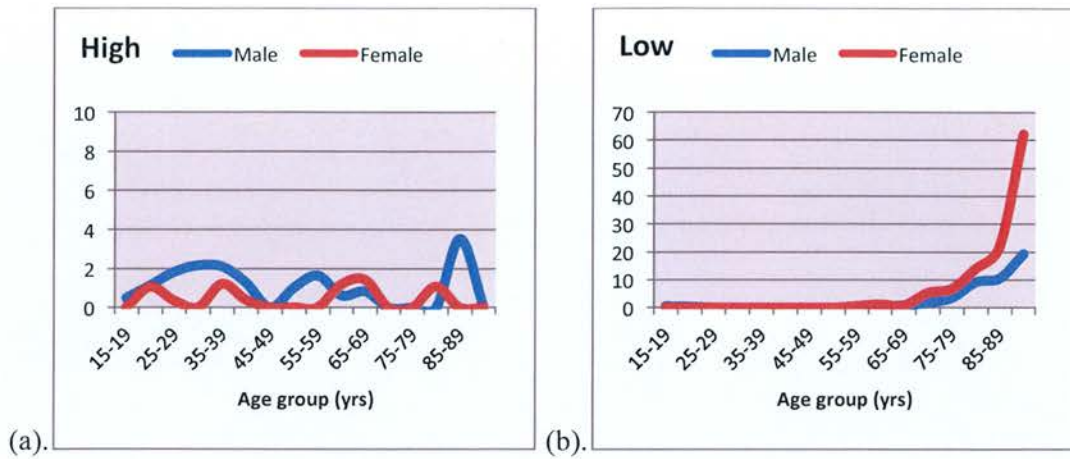


Figure 3.75 (a) The age- and gender-related incidence (n/10,000/yr) of high energy pelvic and acetabular fractures in Edinburgh adults. (b) The age- and gender-related incidence (n/10,000/yr) of low energy pelvic and acetabular fractures.

Fractures of the pelvic ring proper are important orthopaedic injuries. Those resulting from high energy trauma have a high frequency of associated chest injury (60%), long bone fracture (50%), head injury (40%) and abdominal injury (16%)²⁷⁸. Regarding the classification of pelvic ring fractures, Tile²⁷⁹ expanded on previous work carried out with Pennal²⁸⁰ to produce the first mechanistic classification system (Table 3.64). Type A fractures included all avulsions, iliac blade fractures and ring fractures that were undisplaced. Type B1 fractures were known as ‘open book’ injuries with varying degrees of anterior symphyseal disruption and involvement of the strong posterior ligamentous structures (stages 1, 2 and 3). Type B2 and B3 fractures were termed ‘lateral compression’ injuries, with internal (B2) and / or superior (B3) rotation of the affected hemipelvis. Type C injuries encompassed all those with loss of anterior and posterior structural ring integrity; *i.e.* a vertically unstable fracture pattern. C3 fractures had associated acetabular involvement.

	Subtypes
Type A Pelvic ring stable	A1 – fractures not involving the ring (avulsions, iliac blade or crest) A2 – stable minimally displaced fractures of the ring
Type B Rotationally unstable, vertically stable	B1 – open book (three stages) B2 – lateral compression, ipsilateral B3 – lateral compression, contralateral (bucket handle)
Type C Rotationally and vertically unstable	C1 – unilateral C2 – bilateral C3 – with associated acetabular fracture

Table 3.64 The classification of pelvic ring injuries, according to Tile²⁷⁹.

Young and Burgess⁵³ further modified and refined Tile's classification to produce the most widely used system in current use (Fig. 3.76). Lateral compression (LC) injuries all involve anterior ring disruption, as well as a sacral impaction fracture (LC1) or crescent fracture (LC2) on the ipsilateral side. LC3 fractures include an associated open book injury to the contralateral hemipelvis. Anteroposterior compression (APC) injuries equate to the three stages of open book B1 fractures described by Tile. APC1 involve minimal opening (<2.5 cm) of the symphysis and near anatomical posterior anatomy. APC2 injuries involve greater separation of the symphysis, and anterior opening of the sacroiliac joint. In APC3 pelvic injuries, there is additional rupture of the posterior sacroiliac structures. Vertical shear injuries (VS) include all those demonstrating vertical displacement of a hemipelvis, (by definition therefore involving anterior and posterior ring disruption). Finally, Young and Burgess described any fracture displaying properties of more than one injury type as combined mechanism (CM).

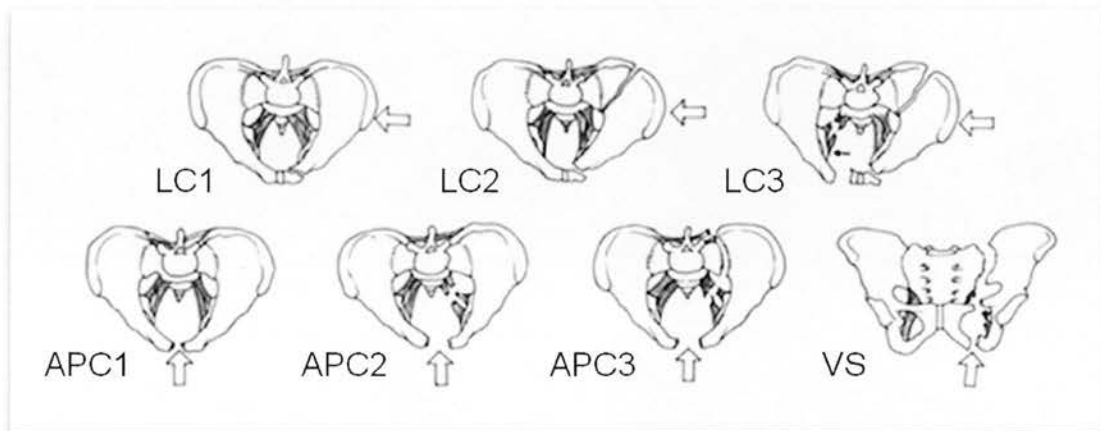


Figure 3.76 The mechanistic classification of pelvic ring injuries, as proposed by Young and Burgess⁵³. Lateral compression injuries involve anterior ring disruption, as well as a sacral impaction fracture (*LC1*) or crescent fracture (*LC2*) on the ipsilateral side, and an associated open book injury to the contralateral hemipelvis (*LC3*). Anteroposterior compression injuries involve anterior ring disruption (*APC1*), anterior sacroiliac opening (*APC2*), and complete posterior ring ligamentous or bony injury (*APC3*). Vertical shear injuries (*VS*) include all those demonstrating vertical displacement of a hemipelvis, (by definition therefore involving anterior and posterior ring disruption).

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Fractures of the acetabulum result from the impact of the femoral head with the acetabular articular surface. The pattern of fracture encountered is related to the direction and magnitude of applied force, the position of the hip joint at the time of impact, and the quality of underlying bone⁵⁴. While many acetabular injuries result from high energy trauma, others

represent low energy fractures through osteoporotic bone. In a series of 259 acetabular fractures, Matta *et al* described the frequency of associated extremity injury (35%), head injury (19%), chest injury (18%), abdominal injury (8%) and spinal injury (4%)²⁸¹. In a more recent study, the same research group documented the increasing significance of acetabular fractures in the elderly²⁸². The most widely used classification system for acetabular fractures is that described by Letournel⁵⁴ (Fig. 3.77). The system is a further refinement of original work performed by the author, alongside Judet and Judet²⁸³.

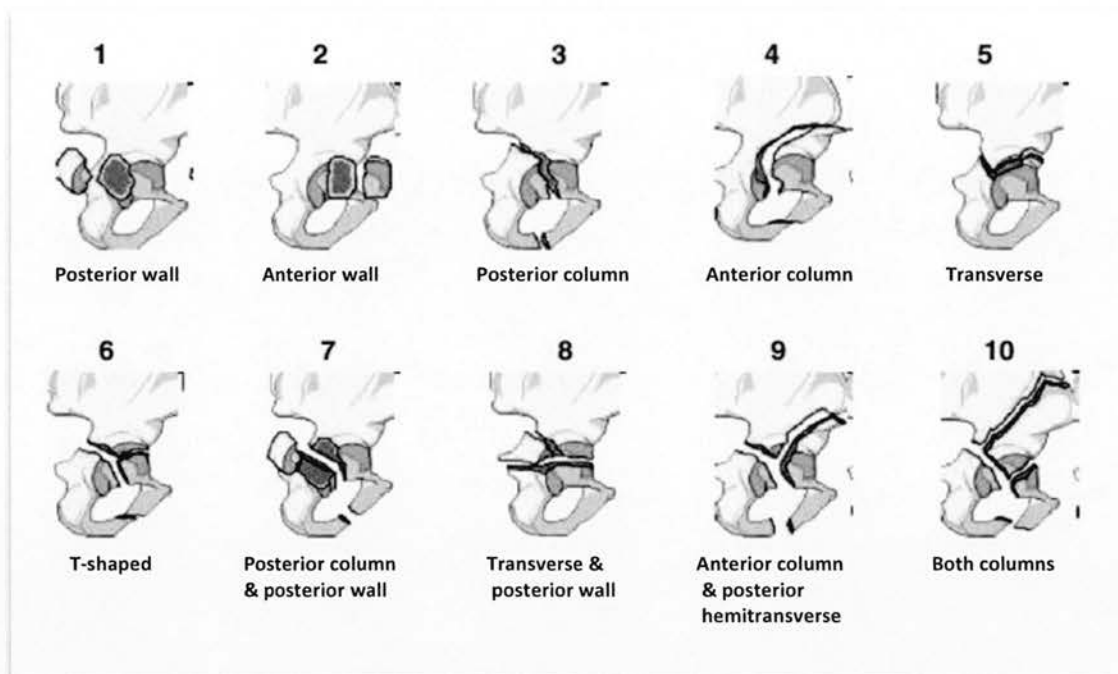


Figure 3.77 The classification of acetabular fractures, as described by Letournel⁵⁴. The five elementary types (*top row, 1-5*) and five associated types (*bottom row, 6-10*) are shown. (Modified with permission from www.orthofracs.com).

Letournel described five elementary and five associated fracture types. Matta²⁸¹ has documented the approximate frequency of each type:

Elementary – anterior column (5%); anterior wall (1%); posterior column (3%); posterior wall (8%); and transverse (3%).

Associated – T-shaped (12%); transverse and posterior wall (23%); posterior column and posterior wall (4%); anterior column and posterior hemitransverse (6%); and both columns (35%).

Table 3.65 compares pelvic ring fractures and acetabular fractures in Edinburgh adults. Patients with pelvic ring fractures represented a larger group of older patients. This was predominantly due to the large number of pubic ramus fractures seen in elderly women. The proportion of patients in both groups presenting with multiple fractures was high (30% to 55%).

	Pelvic ring	Acetabulum	p-value
Fractures (n)	103	18	-
Fracture incidence (n/10,000/yr, 95% CIs)	1.9 (1.5-2.3)	0.3 (0.2-0.5)	-
Gender ratio (M:F, %)	34:66	72:28	$p=0.005^*$
Median age (yrs, IQR)	80 (58-86)	61.5 (33.5-70)	$p=0.017^{**}$
Men	51 (32-82)	69 (35.5-77)	$p=0.479^{**}$
Women	83 (74-90)	42 (26-74.5)	$p=0.024^{**}$
% high energy injuries	30.1	55.6	$p=0.066^*$
% with multiple fractures	30.1	38.9	$p=0.641^*$

Table 3.65 The number and incidence of pelvic ring and acetabular fractures occurring in Edinburgh adults. The age- and gender-related distribution of affected patients is shown, as well as the proportions of injuries associated with high energy trauma and multiple fractures. *Chi square test. **MWU test. Isolated iliac blade, sacrococcygeal and avulsion fractures have been omitted.

Pelvic ring injuries accounted for 103 (80.5%) of 128 pelvic fractures. Three patients suffered more than one pelvic fracture type (two pelvic ring plus acetabular fractures, one pelvic ring plus sacral body fracture). A fall from a height was responsible for each of these combined injuries. The distribution of pelvic ring injuries according to the Tile classification as well as the Young and Burgess system is shown in Figure 3.78. The majority of ring fractures were minimally displaced LC1 injuries involving the pubic ramus.

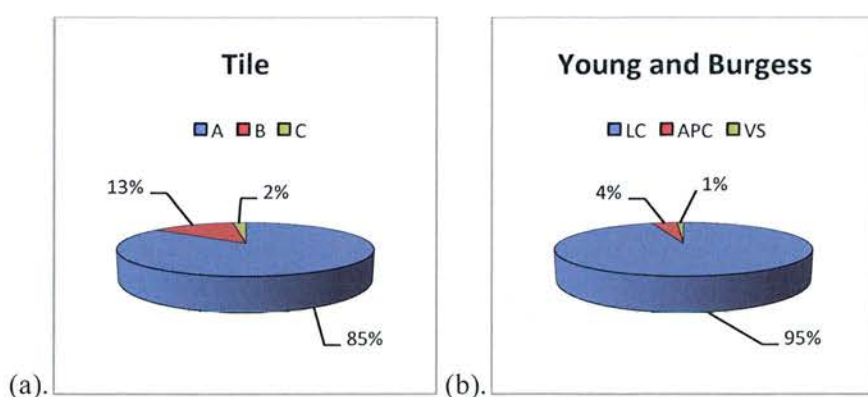


Figure 3.78 The distribution of pelvic ring injuries occurring in Edinburgh adults, and presented according to the Tile²⁷⁹ (a) and Young and Burgess⁵³ (b) classification systems. *LC* = lateral compression; *APC* = anteroposterior compression; *VS* = vertical shear.

Hill *et al* reported on 286 consecutive Edinburgh adults with fractures of the pubic ramus over a seven-year period (1988 to 1994)²⁸⁴. The overall incidence at that time was 0.7/10,000/yr, with a much higher rate observed in patients aged 60 years or more (2.6/10,000/yr). Over the present one-year study period the figures have increased dramatically. A total of 92 pubic ramus fractures were seen (a 124% increase in annual number). The overall incidence was 1.7/10,000/yr (a 142% increase). The incidence in patients aged 60 years or more was 6.8/10,000/yr (a 162% increase). The increase in number of low energy pelvic ring fractures has occurred in conjunction with a decrease in the number of high energy injury patterns. Table 3.66 details the patterns of pelvic fracture encountered depending on the mode of injury responsible.

	High energy	Low energy	p-value
Fractures (n, %)	43 (33.6)	85 (66.4)	-
Fracture incidence (n/10,000/yr, 95% CIs)	0.8 (0.6-1.1)	1.5 (1.2-1.9)	-
Median age (yrs, IQR)	36 (28-54.5)	83.5 (77-90)	$p < 0.001^{**}$
Gender ratio (M:F, %)	73:27	23:77	$p < 0.001^*$
% with multiple fractures	64.4	15.1	$p < 0.001^*$
Ring fractures			
Tile classification (n)			
A	15	72	-
B	13	0	
C	3	0	
Young & Burgess (n)			
LC	26	72	-
APC	4	0	
VS	1	0	
Acetabular fractures			
Letournel (n)			
Elementary	3	7	-
Associated	7	1	
Other types			
Sacrum	2	1	
Iliac blade	1	4	-
Avulsions	1	1	

Table 3.66 The number, frequency and incidence of high energy versus low energy fractures of the pelvis occurring in Edinburgh adults. The age- and gender-related details of affected patients are presented. The distribution of fractures according to anatomical location, and the Tile, Young & Burgess, and Letournel classification systems is also shown. *Chi square test. **MWU test. (LC = lateral compression; APC = anteroposterior compression; VS = vertical shear).

In their Australian series, Balogh *et al* found the distribution of Tile pelvic ring fracture types A, B and C to be 41%, 41% and 18% for high energy fractures, and 98%, 2% and 0% for low energy²⁷⁷. The distribution in the present series is similar for high energy (48%, 42%, 10%) and low energy (100%, 0%, 0%) trauma.

The small number of acetabular fractures recorded was evenly distributed between high and low energy trauma. The associated fracture patterns were more frequently seen in the high energy group. The elementary fractures encountered were anterior wall (n=3), posterior column (n=1), posterior wall (n=3) and transverse (n=3). The associated fractures were T-shaped (n=1), posterior column and posterior wall (n=1), anterior column and posterior hemitransverse (n=1) and both columns (n=5).

Avulsion fractures of the anterior inferior iliac spine are well recognised injuries in young sportsmen²⁸⁵. One such fracture occurred in a 15 year old male patient, injured playing football. Another resulted from significantly higher energy trauma when a 38 year old man fell from a height. There were two fractures of the sacrococcygeal region that occurred in the absence of pelvic ring injury. One coccyx fracture was sustained as an isolated injury by a motorcyclist following a RTA. An elderly female patient sustained a transverse sacral fracture, a scapular body fracture and a head injury following a fall down a flight of stairs, (these injuries proving fatal soon after admission to hospital). Five iliac blade fractures were recorded. Four occurred in women as a result of low energy trauma, and one in a young man following a motorcycle accident.

SECTION 4: THE EFFECT OF SOCIAL DEPRIVATION

Aim. To explore whether an association exists between socioeconomic deprivation and the incidence of adult fractures in Edinburgh.

Hypothesis. The incidence of fractures of the upper limb, lower limb and pelvis is higher in patients from deprived areas than those living in affluent areas

Objective 1. To calculate the incidence of adult fractures in Edinburgh according to population deprivation deciles, and determine if a correlation exists.

Objective 2. To calculate the socioeconomic deprivation fracture ratios for individual adult fracture types and the injury modes involved.

4.1 Patients and methods

The same cohort of adult fracture patients described in Section 3 was used for the socioeconomic deprivation analysis. Details of the criteria used for fracture definition, fracture classification and ascertainment (the numerator), the population at risk (the denominator), causation and multiplicity have been described previously (Section 3.1).

Socioeconomic deprivation

Deprivation data for the population at risk were obtained from Scottish Government sources²⁸⁶. The Scottish Index of Multiple Deprivation (SIMD) combines 38 indicators of deprivation across seven broad domains: income; employment; health; education, skills and training; housing; geographic access to services; and crime. Each of these deprivation domains is weighted based on relative importance (28%; 28%; 14%; 14%; 9%; 5%; 2%) to give the SIMD statisticians the overall deprivation index. The SIMD identifies small area concentrations of deprivation based on postal code groupings known as datazones. Scotland contains 6,505 datazones, and these are ranked from the most deprived (rank = 1) to the least deprived (rank 6,505) areas. The rankings are often displayed as five or ten equal population categories (known as quintiles or deciles). The SIMD provides a *relative*, and not *absolute*, measure of deprivation. It is incorrect to assume that the datazone ranked 50 is twice as deprived as the datazone ranked 100.

For the purposes of this study each postcode in the City of Edinburgh, Midlothian and East Lothian council areas was assigned a SIMD ranking. The population at risk within each deprivation category was derived from Scottish government data, allowing the calculation of fracture incidence in relation to the SIMD (Table 4.1, next page).

Deprivation decile	Men (n)	Women (n)	Both (n)
1 (most)	13,143	15,074	28,218
2	13,602	15,427	29,029
3	20,931	23,691	44,622
4	20,950	23,708	44,658
5	21,307	23,959	45,266
6	21,033	23,611	44,644
7	19,497	21,904	41,401
8	27,325	30,750	58,075
9	27,640	31,052	58,692
10 (least)	67,177	75,650	142,826

Table 4.1 The number of male and female adults in Edinburgh, arranged in order of decreasing levels of socioeconomic deprivation, as measured by the Scottish Index of Multiple Deprivation. Data were obtained from Scottish Government sources²⁸⁶.

Statistical analysis

Microsoft Excel 2007 (Microsoft Corp, Redmond, Washington) and SPSS version 18.0 (SPSS, Chicago, Illinois) were used to undertake statistical analyses, and professional statistical input was used for correlation and logistic regression analyses. Continuous data were checked for normality using the Kolmogorov-Smirnov test and are presented in terms of the median, range (R) and interquartile range (IQR). A two-tailed p -value of <0.05 was considered statistically significant. Fracture incidence was calculated as the number of fractures per 10,000 head of population per year ($n/10,000/yr$).

The SIMD decile system (ten categories) was used to determine the relationship between socioeconomic deprivation and fracture incidence while the SIMD quintile system (five categories) was used to calculate socioeconomic deprivation fracture ratios (SDFRs) for fracture types and modes of injury. To calculate the SDFR the fracture incidence in quintile 1 (most deprived) was divided by that of quintile 5 (most affluent).

The Pearson correlation coefficient (r) was calculated to reflect the extent of a linear relationship between fracture incidence and deprivation decile. Observed correlations were described as strong ($r=0.5-1.0$), moderate ($r=0.30-0.49$) or weak ($r=0 -0.29$) according to Cohen's guidelines²⁸⁷.

Finally, the association between fracture incidence, patient age, patient gender, mode of injury and deprivation category was tested by logistic regression analysis in order to determine the effect of deprivation after controlling for potentially confounding variables.

4.2 Results

Ten fracture types accounted for 82.5% of all adult fractures (Table 4.2), and formed the basis of the present socioeconomic deprivation analysis.

	(n)	Median age (yrs, IQR)	Gender ratio (M/F)
Distal radius	1,124	62 (37-76)	30/70
Proximal femur	821	83 (76-88)	27/73
Metacarpus	737	25 (20-38)	79/21
Finger	677	36 (23-50)	65/35
Ankle	631	50 (31-64)	46/54
Proximal humerus	502	70 (55-80)	31/69
Metatarsus	429	44 (26-60)	37/63
Clavicle	280	36.5 (23-59)	71/29
Proximal radius	263	43 (28-56)	47/53
Carpus	205	28 (22-46)	70/30

Table 4.2 The ten most frequently encountered fracture types, occurring in Edinburgh adults, and comprising 82.5% of all fractures encountered. The age- and gender-related distribution of affected patients is also presented.

The association between the incidence of all fractures and the socioeconomic deprivation status of the patient is illustrated in Figure 4.1. A strong inverse linear relationship ($r = -0.97$) was seen overall and was more pronounced in men ($r = -0.92$) than in women ($r = -0.66$). Peak incidence in men was 197.1/10,000/yr in the most deprived decile, falling to 99.7/10,000/yr in the least deprived areas. In women, the peak fracture incidence was noted in decile 2 (154.3/10,000/yr).

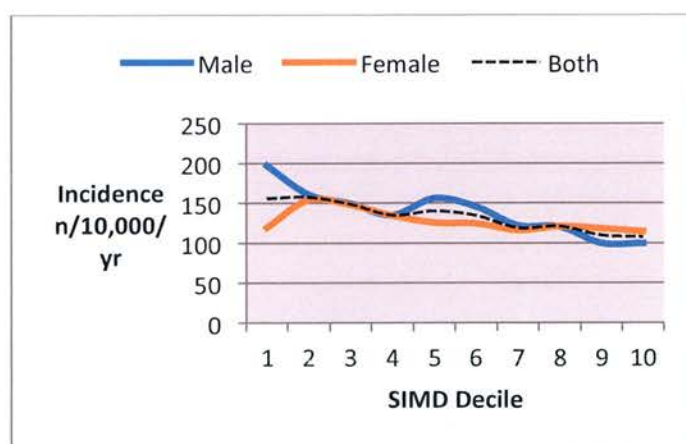
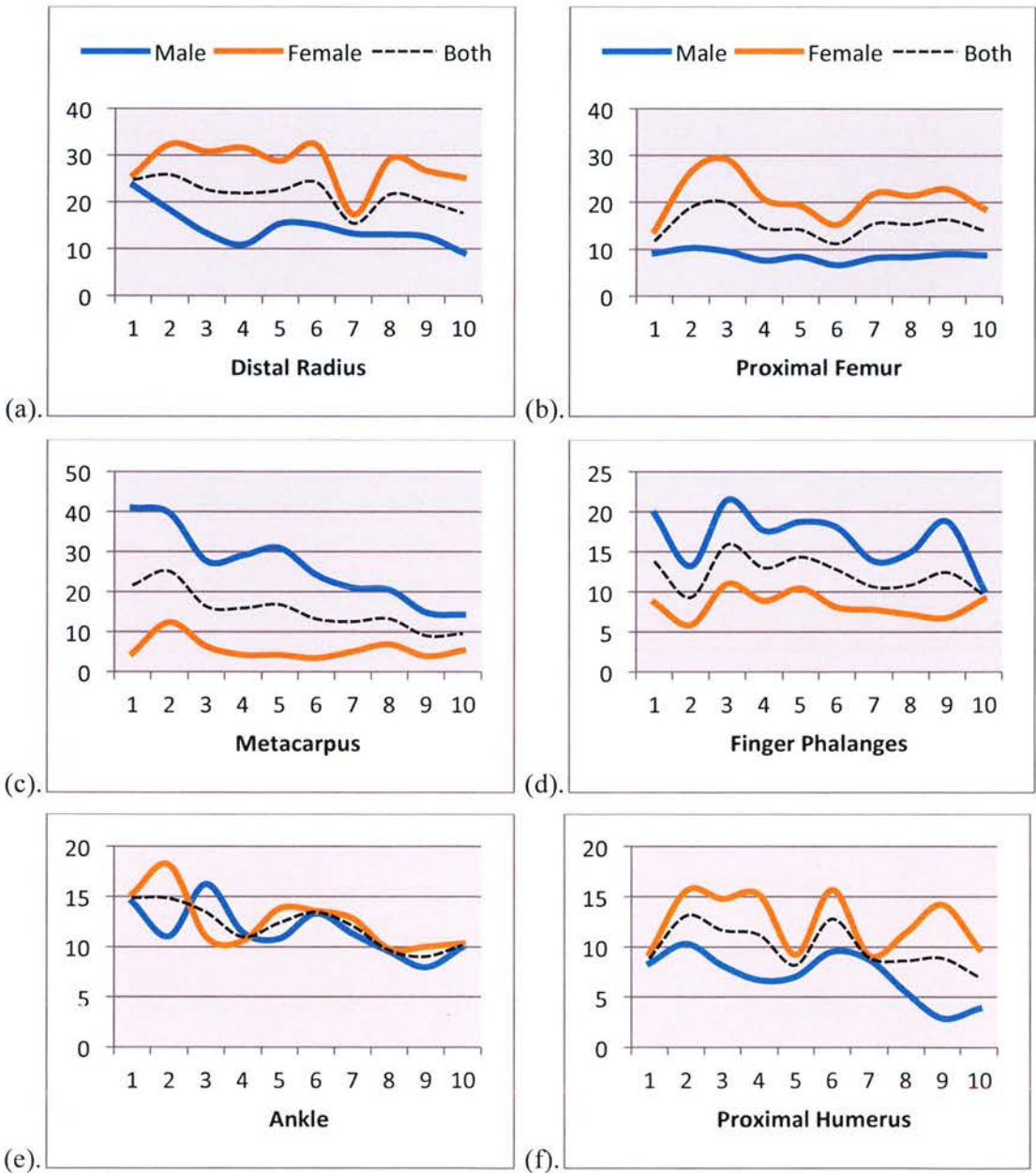


Figure 4.1 The gender-related incidence of acute fractures occurring in Edinburgh adults, according to socioeconomic deprivation. (Decile 1 = most deprived; decile 10 = least deprived).

Fracture types and overall correlation

The distribution curves generated by the ten most common fracture types are shown below (Fig. 4.2). A strong correlation ($r=0.5-1.0$) between overall incidence and deprivation was identified for fractures of the metacarpus ($r= -0.91$), ankle ($r= -0.86$), distal radius ($r= -0.73$), metatarsus ($r= -0.66$), proximal humerus ($r= -0.56$) and carpus ($r= -0.55$). A moderate correlation ($r=0.30-0.49$) was identified for fractures of the finger phalanges ($r= -0.42$), proximal radius ($r= -0.39$) and clavicle ($r= -0.30$). The correlation between proximal femoral fracture incidence and deprivation was weak ($r= -0.14$).



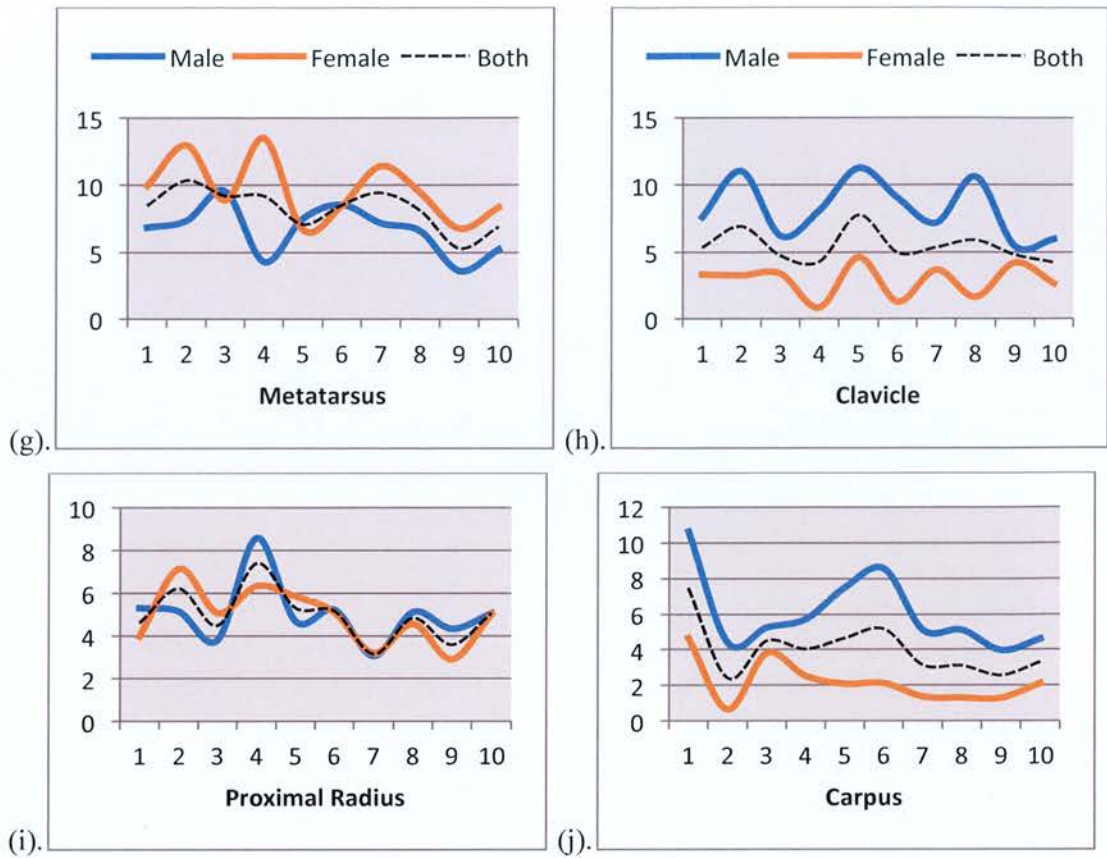


Figure 4.2 The gender-related incidence (n/10,000/yr) of ten (a-j) fractures types, occurring in Edinburgh adults, according to socioeconomic deprivation. Scottish index of multiple deprivation deciles 1 to 10 are shown on the x-axes. (*Decile 1 = most deprived; decile 10 = least deprived*).

Fractures types and gender-related correlations

The strongest correlations in male patients were seen with fractures of the metacarpus ($r = -0.96$), distal radius ($r = -0.74$), proximal humerus ($r = -0.74$) and ankle ($r = -0.70$). In women the majority of correlations were weak to moderate, with the exception of those seen in fractures of the ankle ($r = -0.68$) and carpus ($r = -0.51$). After controlling for confounding variables using multiple regression analyses, the majority of gender-related correlations remained statistically significant (Tables 4.3 and 4.4).

MEN	SIMD Deciles										p-value
	1	2	3	4	5	6	7	8	9	10	
Distal radius	23.6	18.4	13.4	11.0	15.5	15.2	13.3	13.2	12.7	9.2	<0.001
Metacarpal	41.1	39.7	27.7	29.1	31.0	24.2	21.0	20.5	14.8	14.3	<0.001
Finger phalanges	19.8	13.2	21.5	17.7	18.8	18.1	13.8	15.0	18.8	10.3	<0.001
Ankle	14.5	11.0	16.2	11.5	10.8	13.3	11.3	9.5	8.0	10.0	<0.001
Proximal humerus	8.4	10.3	8.1	6.7	7.0	9.5	8.7	5.5	2.9	3.9	<0.001
Metatarsal	6.8	7.4	9.6	4.3	7.5	8.6	7.2	6.6	3.6	5.2	<0.001
Clavicle	7.6	11.0	6.2	8.1	11.3	9.0	7.2	10.6	5.4	6.0	<0.001
Proximal radius	5.3	5.1	3.8	8.6	4.7	5.2	3.1	5.1	4.3	5.1	<0.001
Carpus	10.7	4.4	5.3	5.7	7.5	8.6	5.1	5.1	4.0	4.6	<0.001

Table 4.3 The incidence (n/10,000/yr) of fracture types in men, according to the Scottish Index of Multiple Deprivation (SIMD) population decile. The pink shaded cells represent fracture types where only a weak or moderate correlation exists ($r < 0.50$). There was no significant correlation seen with fractures of the proximal femur ($p = 0.06$).

WOMEN	SIMD Deciles										p-value
	1	2	3	4	5	6	7	8	9	10	
Distal radius	25.9	32.4	30.8	31.6	28.8	32.2	17.3	29.3	26.7	25.2	<0.001
Proximal femur	13.9	26.6	29.1	20.7	19.2	15.2	21.9	21.5	22.9	18.6	<0.001
Metacarpal	4.6	12.3	6.3	4.2	4.2	3.4	5.0	6.8	3.9	5.3	<0.001
Finger phalanges	8.6	5.8	11.0	8.9	10.4	8.0	7.8	7.2	6.8	9.1	<0.001
Ankle	15.3	18.2	11.0	10.5	13.8	13.6	12.8	9.8	10.0	10.3	<0.001
Proximal humerus	9.3	15.6	14.8	15.2	9.2	15.7	9.1	11.4	14.2	9.8	<0.001
Metatarsal	10.0	13.0	8.9	13.5	6.7	8.5	11.4	9.4	6.8	8.3	<0.001
Clavicle	3.3	3.2	3.4	0.8	4.6	1.3	3.7	1.6	4.2	2.6	<0.001
Proximal radius	4.0	7.1	5.1	6.3	5.8	5.1	3.2	4.6	2.9	5.0	<0.001
Carpus	4.6	0.6	3.8	2.5	2.1	2.1	1.4	1.3	1.3	2.1	<0.001

Table 4.4 The incidence (n/10,000/yr) of fracture types in women, according to Scottish Index of Multiple Deprivation (SIMD) population decile. The pink shaded cells represent fracture types where only a weak or moderate correlation exists ($r < 0.50$).

Modes of injury and gender-related correlations

Table 4.5 (next page) shows the incidence of fractures, in Edinburgh men and women, presented according to the mode of injury involved. In women, all modes of injury demonstrated a positive correlation between fracture incidence and deprivation over all ten deciles (range, $r = -0.54$ to $r = -0.71$). Closer analysis of the fracture incidences revealed that

most of this effect was due to deciles 1 and 2. When these two most deprived deciles were removed, and deciles 3 – 10 were examined, a significant correlation remained for fractures where the mode was unknown or uncertain ($p = 0.01$) and for fractures sustained by falls from height (trend, $p = 0.06$).

	SIMD Deciles										p-value
	1	2	3	4	5	6	7	8	9	10	
Men											
Simple fall	181.6	107.5	46.7	23.1	44.4	35.7	46.1	28.8	27.2	29.4	<0.001
Sport	102.4	59.4	34.1	19.6	29.9	27.9	49.9	22.3	26.1	27.3	<0.001
Direct blow	129.7	74.8	41.1	14.1	34.4	21.0	28.0	15.1	12.5	9.9	<0.001
Other	35.5	14.7	7.0	2.0	5.9	5.5	6.5	2.5	3.7	1.6	<0.001
RTA	47.8	23.4	16.4	3.1	13.6	9.7	13.1	8.6	6.8	6.1	<0.001
Stairs	21.9	6.0	2.8	2.4	5.0	3.6	6.1	3.6	2.6	1.3	<0.001
Height	35.5	24.7	8.9	5.1	8.6	5.8	7.0	4.3	4.5	3.5	<0.001
Women											
Simple fall	337.4	210.8	74.8	53.5	127.6	72.7	128.3	71.4	90.4	71.2	<0.001
Sport	18.9	8.8	6.3	3.8	6.7	4.1	8.9	7.6	5.9	4.9	<0.001
Direct blow	22.5	11.2	5.9	2.8	9.9	8.6	9.7	5.4	6.5	2.5	<0.001
Other	15.4	8.8	4.9	1.4	4.0	3.0	3.0	3.5	2.8	2.4	<0.001
RTA	15.4	4.7	3.1	0.4	3.6	3.3	3.0	1.3	2.3	1.0	<0.001
Stairs	20.1	18.8	2.5	1.4	5.9	4.6	11.4	5.1	3.9	2.7	<0.001
Height	14.2	4.1	2.5	1.0	1.2	2.0	2.1	1.3	0.6	0.7	<0.001
Nil / spont	13.0	2.4	0.7	0	0.8	1.0	1.3	0.3	0.8	0	<0.001

Table 4.5 The incidence (n/10,000/yr) of fractures in male and female adults in Edinburgh, according to the injury mode involved, and arranged in order of decreasing deprivation as measured by the Scottish Index of Multiple Deprivation (SIMD). Decile 1 represents the most deprived, decile 10 the least deprived. There was no significant correlation seen in males with spontaneous fractures ($p=0.61$). (RTA = road traffic accident; Stairs = fall down stairs; Height = fall from height).

In men, all injury modes showed a strong and significant correlation over the ten deciles (range, $r = -0.60$ to $r = -0.79$). There was also significant correlation for fractures sustained by direct blows or assaults ($p < 0.001$), following falls from height ($p = 0.019$), RTAs ($p = 0.034$) and simple falls ($p = 0.05$) when deciles 1 and 2 were excluded. This suggests that deprivation in men has a broader effect on fracture incidence than in women. Of note, there was no correlation between fracture incidence and deprivation in pathological or spontaneous fractures in male patients.

Socioeconomic deprivation fracture ratios

The SDFR for all fractures was 1.45, meaning that patients living in the most deprived quintile had a fracture incidence 45% higher than those living in the most affluent quintile. The discrepancy was more pronounced in men (SDFR of 1.79) than in women (SDFR of

1.19). The ratio for open fractures was 1.71. The SDFR for the ten most common fracture types is shown in Table 4.6.

Men		Women	
	SDFR		SDFR
Distal radius	2.05	Distal radius	1.79
Proximal femur	1.10	Proximal femur	1.02
Metacarpus	2.79	Metacarpus	1.75
Finger	1.29	Finger	0.86
Ankle	1.35	Ankle	1.64
Proximal humerus	2.61	Proximal humerus	1.13
Metatarsus	1.50	Metatarsus	1.46
Clavicle	1.61	Clavicle	1.06
Proximal radius	1.08	Proximal radius	1.27
Carpus	1.69	Carpus	1.40

Table 4.6 The Social Deprivation Fracture Ratios (*SDFRs*) for the ten most common fracture types in men and women.

SECTION 5: DISCUSSION AND CONCLUSIONS

5.1 Fracture epidemiology research methods

Many sources of error exist in epidemiological fracture research. Section 1.2 has highlighted some of the methodological challenges that must be addressed by researchers when conducting such investigations. By carefully defining and documenting the research methods used, authors can design epidemiological fracture studies that are reproducible across different study populations and over different time periods. In doing so, they can produce results that are broadly comparable, from which meaningful trends can be identified and conclusions drawn.

Careful analysis of the available adult fracture epidemiology literature (Table 1.2) reveals a marked variation in overall fracture incidence reported by nine investigations. These studies have reported fracture incidence in different countries and at various time periods in the last 25 years, but the most striking difference between reports has been the methods employed in gathering numerator data, *i.e.* accurately defining, classifying and ascertaining cases of fracture.

Between 2002 and 2004, Donaldson *et al*⁹² employed a patient questionnaire strategy to determine adult fracture patterns and reported the highest overall adult fracture incidence of any of the nine investigations. The advantage of this questionnaire methodology was the ability of the authors to pick up fractures treated primarily by general practitioners and allied health care providers; injuries which often do not present to orthopaedic services (*e.g.* rib fractures, vertebral fractures in the elderly, minor toe and finger fractures). The main disadvantage of the report, in keeping with any questionnaire study, was the reliance upon accurate patient recall²⁸⁸⁻²⁹⁰. Providing a clear definition of fracture has been shown to improve patient recall, as has limiting the length of time over which patients are asked to recall injuries²⁸⁸. Patient recall has been used more extensively in the sports injury literature. Twellaar *et al* found that sports participants recalled 61% of their injuries accurately one year later²⁹¹. Gabbe *et al* compared retrospective and prospective sports injury data for the same 12 month period and found that 80% of Australian football players could accurately recall the anatomical site of injury, but only 60% could recall the correct diagnosis²⁹².

Notably, they concluded that self-reporting methodology in sports injury research could not be relied upon with confidence.

In contrast to the UK, where a single healthcare system provides medical services exclusively for the entire geographic population, most geographic regions of the USA are served by multiple healthcare systems⁹³. Brinker and O'Connor therefore obtained medical insurance company data in an attempt to estimate the incidence of fractures in patients referred for orthopaedic treatment in Texas, USA⁹³. The population of interest included insured, employed adults and their dependents, but uninsured and retired individuals were not studied. The authors reported an overall fracture incidence similar to that reported by other studies whose numerator data were taken from orthopaedic sources (Table 1.2), but by their own admission they failed to obtain fracture data from patients aged 65 years or older. Given that the incidence of most fractures increases with advancing patient age, it must be assumed that the overall and gender-related fracture incidences presented in this report represent an underestimation of the true rate of fractures in Texas (as measured by insurance company numerator data).

Three investigations reporting adult fracture incidence used numerator data obtained from emergency department (ED) databases or coding systems, and reported rates of adult fracture of between 21/1,000/yr and 23/1,000/yr^{87,90,91}. These investigations were performed in three different countries (UK, Norway, USA), gathering data from three different decades (1970s, 1980s, 1990s), yet the reported fracture incidences are remarkably similar. The same can be said of the three investigations where numerator data were taken from orthopaedic sources^{86,88,89}. These studies were performed between 1980 and 2000 in different regions of the UK, yet the reported rates of fracture are similar (9/1,000/yr to 13/1,000/yr). The fracture incidences reported by orthopaedic studies are strikingly lower than those reported by ED investigations. It would seem apparent, therefore, that the factor most responsible for the wide variation in reported fracture incidence in the literature is the methodology employed to obtain numerator data.

The majority of UK epidemiological health care research utilises the UK General Practice Research Database (GPRD). This database comprises the computerised medical records of a large number of participating general practitioners, and its use allows researchers to analyse a regionally diverse group of patients across a large geographical area. If the keyword search 'general practice research database' is entered into the Ovid MEDLINE search engine

(up to and including the year 2008), 563 results are found. The database has been reportedly validated on a number of occasions²⁹³⁻²⁹⁵, with a true positive rate ranging from 70% to 95% depending on the diagnosis or disease of interest.

Use of the GPRD for epidemiological fracture research has the advantage of providing researchers with numerator fracture data for a large cross-section of the UK population, and van Staa and colleagues attempted this in their report published in 2001⁹⁴. The authors reported an overall fracture incidence in keeping with orthopaedic investigations, although the validity of fracture data from the GPRD has not been formally reported.

Authors	Year	Journal	Risk factor of interest
Abel KM <i>et al</i> ²⁹⁶	2008	Journal of Clinical Psychiatry	Psychiatric illness
Gallagher AM <i>et al</i> ²⁹⁷	2008	Journal of Bone & Mineral Research	Bisphosphonates
Kaye JA and Jick H ²⁹⁸	2008	Pharmacotherapy	Proton pump inhibitors
Lewis NR <i>et al</i> ²⁹⁹	2008	Alimentary Pharmacology & Therapeutics	Dermatitis herpetiformis
Meier C <i>et al</i> ³⁰⁰	2008	Archives of Internal Medicine.	Thiazolidinediones
Wilting I <i>et al</i> ³⁰¹	2007	Bone	Lithium
van Staa TP <i>et al</i> ³⁰²	2007	Rheumatology	Bisphosphonates and Glucocorticoids
de Vries F <i>et al</i> ³⁰³	2007	Calcified Tissue International	Beta-blockers
Howard L, Kirkwood G and Leese M ³⁰⁴	2007	British Journal of Psychiatry	Schizophrenia
Yang YX <i>et al</i> ³⁰⁵	2006	JAMA	Proton pump inhibitors
Solaymani-Dodaran M <i>et al</i> ³⁰⁶	2006	Gastroenterology	Primary biliary cirrhosis
van Staa TP <i>et al</i> ³⁰⁷	2006	Arthritis & Rheumatism	Rheumatoid arthritis
Souverein PC <i>et al</i> ³⁰⁸	2006	Neurology	Anti-epileptic medication
Hugenholtz GW <i>et al</i> ³⁰⁹	2005	Bone	Anti-psychotic medication
de Vries F <i>et al</i> ³¹⁰	2005	European Respiratory Journal	Chronic obstructive airways disease
van Staa TP <i>et al</i> ³¹¹	2005	QJM	Glucocorticoids
Souverein PC <i>et al</i> ³¹²	2005	Epilepsia	Epilepsy
Kaye JA and Jick H ³¹³	2004	Injury Prevention	Lower limb fractures
Schlienger RG <i>et al</i> ³¹⁴	2004	JAMA	Beta-blockers
Torgerson DJ <i>et al</i> ³¹⁵	2004	Annals of the Rheumatic Diseases	Vertebral fractures
Card T <i>et al</i> ³¹⁶	2004	Gut	Inflammatory bowel disease and Corticosteroid use

Table 5.1 The results of a search of the Ovid MEDLINE database from 2004 to 2008, identifying adult studies utilising the General Practice Research Database as a source of fracture data. The study authors, year of publication, journal, and disease or association of interest are shown. (Search criteria: *keyword* = general practice research database; *title* = fracture*; *limits* = years 2004-2008, humans, English language).

The GPRD derives its fracture data from two sources: inpatient discharge letters and ED records. These data sources are not coded or collated by orthopaedic clinicians, and it seems studies using ED numerator data report fracture incidences twice that of those using orthopaedic data (Table 1.2). In recent years, the GPRD has proven to be a hugely popular source of fracture data for epidemiological research purposes. A large number of studies have attempted to identify risk factors for fracture in various patient groups by obtaining fracture cases and matched controls from the database. Researchers have made the assumption that GPRD numerator data are accurate, and have been obtained from valid and reliable sources. An analysis of the recent fracture literature utilising the GPRD was performed using a second Ovid MEDLINE search. This search (limited to studies published between 2004 and 2008) identified articles containing 'fracture(s)' in the title and 'general practice research database' as a keyword. Twenty six results were returned. Five studies dealt with fracture patterns in the paediatric population³¹⁷⁻³²¹. The remaining 21 studies analysed adult fractures patterns (Table 5.1, previous page).

Section 2 of this thesis aimed to investigate the effect of employing two different research methods of obtaining numerator data, on the number and patterns of fractures reported. The population of interest consisted of a cohort of adult outpatients referred from the ED to the orthopaedic trauma unit (OTU) at a large teaching hospital in Edinburgh. The ED injury and fracture coding was directly compared with that of the OTU.

The results have shown that a marked difference exists between the two sources of numerator data. The positive predictive value (PPV) of a correct ED outpatient fracture diagnosis was only 73.8%. For every four fractures (as determined by the ED database), one of these had been coded incorrectly. This has clear implications for the Edinburgh region, and perhaps other regions in the UK with similar population demographics, in terms of how future epidemiological fracture research should be carried out. Studies using ED numerator data are likely to overestimate adult fracture incidence when compared to those investigations obtaining data from orthopaedic sources. The extent of overestimation can not accurately be predicted from this study, as the comparison was restricted to outpatient cases and patients with fractures treated on an inpatient basis were not included.

Several common fracture types were miscoded more frequently, and were associated with PPVs poorer than the average of 73.8%. These included fractures of the carpus, proximal tibia, proximal radius, calcaneus, talus and midfoot. It is the difficulty in accurately

ascertaining cases of fracture from these anatomical regions that accounted for the largest proportion of the overall difference seen between the two sources of data. Future research utilising ED fracture data may benefit from recognising the 'false positive rate' of many common fracture types, and researchers might consider adjusting case numbers in order to reflect the number of probable misdiagnoses.

Differences in staffing of EDs between regions will also affect the discrepancy between ED and orthopaedic fracture recording. Senior ED clinicians and OTU clinicians had a lower false positive referral rate than junior ED colleagues (Table 2.5), and clinician seniority remained predictive of diagnostic accuracy after multiple regression analyses. It is accepted that in clinical practice senior clinicians are called upon to review more severe or difficult cases, and this may have an effect on the accuracy of referral. Of interest, nurse practitioners performed equally as well as junior ED doctors, further confirming previous studies in this area³²²⁻³²⁴. In Edinburgh, the majority of patients with minor musculoskeletal injuries were seen and treated by junior ED clinicians. In departments where the proportion of middle grade and senior doctors is higher, the overall false positive fracture diagnosis rate is likely to be lower.

This study has been undertaken at a time when the majority of patients suffering minor musculoskeletal injuries in the UK are seen and treated by junior ED clinicians, before any appropriate onward referral for orthopaedic review. Many smaller emergency departments and minor injury units are not staffed by middle or senior grade medical clinicians, and instead patients with fractures are initially seen and treated by extended scope non-medical practitioners and specialist nursing staff. Recent systems within the ED in Edinburgh, and most likely in many regions of the UK, have routinely used referral to the orthopaedic fracture clinic as a means of quality control and as a 'safety net' to prevent missed injuries. It is therefore of no surprise that many injuries encountered in the ED, and deemed to represent potential fractures, are later proven to be minor sprains or strains. This study has shown that a large number of injuries to the carpus, proximal radius, hindfoot and midfoot fall into this category.

Admittedly, this investigation was limited to outpatient orthopaedic referrals, and did not investigate the potential discrepancy between inpatient admission and discharge diagnoses. A systematic review of inpatient discharge coding accuracy in the UK concluded that discharge coding performed by administrative staff is generally 'highly accurate'³²⁵.

Notably, all inpatient fracture coding in Edinburgh is performed by orthopaedic clinicians rather than administrative staff, but it is accepted that this will not be the case in many other regions. Future work aimed at determining the differences between ED and orthopaedic numerator fracture data should incorporate an analysis of both outpatient and inpatient data.

At the present time, a major modernisation of the orthopaedic fracture clinic design is underway in Scotland. The redesign aims to reduce overcrowding, reduce patient waiting times, and avoid unnecessary referrals to the fracture clinic. Notably, the proposed redesign involves the careful review of the medical records and plain radiographs of each newly referred patient, and is performed by a senior orthopaedic clinician. This novel approach to the review and management of patients with fractures treated on an outpatient basis has important implications for epidemiological fracture research carried out in Scotland, especially if the redesign template is adopted in all Scottish hospitals. The redesign should be viewed as an opportunity for researchers to collect and analyse numerator fracture data on a national scale. Most importantly, it will allow fracture data to be obtained from orthopaedic sources and will minimise the potential ascertainment error associated with the use of ED fracture data.

5.2 Patterns of fractures in adults

Section 3 of this thesis examined the range and pattern of acute fractures occurring in Edinburgh adults. The organisation of trauma and orthopaedic services in the Edinburgh region is well suited to epidemiological fracture research. The vast majority of Edinburgh residents who sustain musculoskeletal injuries are seen and treated in a single emergency department at the Royal Infirmary of Edinburgh, with a smaller proportion of patients assessed and triaged at a single minor injuries unit at the Western General Hospital, situated in the northern part of the city. The orthopaedic trauma unit receives all referrals from these institutions for fractures occurring in Edinburgh adults requiring treatment on an inpatient or outpatient basis.

The Scottish Research Trust into Trauma (SORT-IT) has collected and recorded data on all trauma referrals to the orthopaedic trauma unit since 1988. Two published reports have documented the epidemiology of fractures in Edinburgh adults: Singer *et al* provided data collected between 1992 and 1993 (24 months)⁸⁹, and Court-Brown and Caesar presented the findings of their study carried out in 2000 (12 months)⁸⁸. The methods used to identify and categorise fractures have remained unchanged since the introduction of the trauma unit database, allowing for some meaningful comparisons between studies to be made. In contrast, comparisons with published studies performed elsewhere in the UK and abroad are limited by the variety of methods used to collect numerator fracture data. The geographical catchment area of the Royal Infirmary includes the City of Edinburgh, Midlothian and East Lothian council areas, and their populations form the denominator for epidemiological research. Population numbers have been provided by the General Register Office for Scotland and are based upon regional results from the 1991 and 2001 Scottish population census polls¹¹¹.

Since 1992, when Singer *et al* examined fractures in Edinburgh adults⁸⁹, the population served by the orthopaedic trauma unit has fallen from 595,672 to 545,081 persons. This represents a decrease in population size of 8%, although the proportions of men and women have remained constant during this time (52% women). Of particular note has been the increase in the proportion of elderly men in the Edinburgh catchment area. The number of men aged 80 years or more has grown from 7,151 in 1992 to 9,266 in 2007, an increase of 30%. Men aged 90 years or older now number more than 1,000 when in 1992 there were less than 500. The number of women aged 80 years or more has actually fallen by 3% from

19,103 in 1992 to 18,435 in 2007. However, the number of women aged 90 years or older has increased by 26%, from 2,558 to 3,219.

Ever since the earliest published study on adult fracture patterns was produced in 1959 by Buhr and Cooke⁸⁴, researchers have reported a bimodal distribution of fracture incidence in men and a unimodal distribution in women^{85, 86, 88, 89}. The overall distribution of adult fractures analysed in this thesis, and shown in Figure 3.2, is no different and illustrates the gradual age-related rise in fracture incidence in adults of both genders. In 1992⁸⁹, the progressive rise in female fracture incidence began in women aged 40 to 44 years, and the present study shows that this rise still commences before the onset of menopause, in women aged between 45 and 49 years. The lowest fracture incidence in women remains in those aged 25 to 39 years. This broadly coincides with the period of adult peak bone mass, although behavioural and fall-related factors also contribute to fracture occurrence. The pattern of fracture incidence in Edinburgh men has changed very little in 15 years. An early peak male age-adjusted incidence occurs in the youngest age groups, and is then followed by a gradual and steady decline in fracture rates until the age of 60 years at which point male fracture incidence increases again, rising progressively to a second peak in the elderly.

Singer *et al*, using standardised methodology, identified 16,400 fractures over a two-year period in Edinburgh⁸⁹. They reported the overall incidence of acute fractures in Edinburgh adults as 129.1/10,000/yr, slightly higher in men (131.5/10,000/yr) than in women (127.0/10,000/yr). The present series contains 6,800 fractures, with an overall incidence of 125.6/10,000/yr. Once again, the rate of fracture was higher in men (126.5/10,000/yr) than in women (124.8/10,000/yr). It must be noted that Singer *et al* included all vertebral fractures in their analysis, so the two series are not strictly comparable. However, Court-Brown and Caesar⁸⁸ encountered only 40 vertebral fractures in the Edinburgh population in 2000 using the same research methodology, and it is therefore unlikely that the addition of vertebral fractures to the present series would alter the overall fracture incidence. Women suffered 52% of all fractures encountered in the present cohort, proving that little has changed in terms of the gender-related distribution of adults fractures in Edinburgh since 2000 (51%) and 1992 (52%).

The overall incidence of fractures in men has fallen between 1992 and 2007. The early peak in male age-adjusted incidence affecting men between 15 and 24 years of age has fallen slightly (24/1,000/yr vs. 21/1,000/yr) during the 15 year period. The second peak fracture

incidence in men, affecting those aged 90 years or more, has increased by some margin (40/1,000/yr vs. 52/1,000/yr), and likely represents the increasing burden of osteoporosis in the male Edinburgh population as their life expectancy improves³²⁶. In contrast, the age-adjusted incidence of fractures in women has changed very little between 1992 and 2007, with the exception of elderly female groups. The fracture rates in women aged 70 to 79 years (26/1,000/yr vs. 23/1,000/yr), 80 to 89 years (48/1,000/yr vs. 45/1,000/yr), and 90 years or more (78/1,000/yr vs. 69/1,000/yr) have fallen by approximately 10%. According to Scottish government sources, the total number of adults in Scotland aged 75 years or more is predicted to increase 80% by the year 2035³²⁷. It is possible that future growth in the number of Edinburgh's elderly inhabitants will bring with it a comparable rise in elderly fracture numbers. Perhaps the greatest proportional increase will be observed in elderly men, rather than elderly women.

The circumstances surrounding fracture occurrence in this thesis have been termed the modes of injury. Injury modes were determined according to arbitrarily chosen criteria, as described in Table 3.3. Many of the categories were not mutually exclusive, and some were far easier to determine (*e.g.* fall from a height, road traffic accident) than others (*e.g.* sports-related, 'other'). The description of modes of injury has not been standardised in any of the published fracture epidemiology literature, and so detailed comparisons between the injury mode results presented in this thesis and existing epidemiological literature must be made cautiously.

The results shown in Section 3.3 have shown that a simple fall from a standing height was the commonest cause of acute fractures in Edinburgh adults, accounting for 54% of the total number. The frequency of simple fall fractures was noted to increase with advancing patient age; a trend already well described in the published literature¹¹⁵⁻¹¹⁷. In young adults (15-39 yrs) simple falls accounted for 22% of fractures, in those aged between 40 years and 59 years of age their frequency was 48%, and in the oldest age group (60 yrs or more) the frequency of simple fall fractures was 84%. In young adults, simple falls caused more upper limb fractures than lower limb fractures, while the reverse was true in the elderly. This pattern of injury is generally accepted to be due to the difficulties in older adults using the upper limb to break their fall.

Simple falls have long been associated with musculoskeletal injury, particularly in older adult groups. According to injury prevention research, one-quarter of all presentations to

emergency departments in the United States is due to simple falls, and the majority of affected patients are aged 75 years or older^{115,117}. The frequency of falling increases with advancing age, and it has been estimated that one-third of adults aged 65 years or older, and one-half of care home residents, will fall each year¹¹⁶. Many simple falls do not result in serious injury but Finnish researchers believe that 5% of simple falls in elderly adults result in a fracture¹¹⁶. Lower limb fractures in the elderly carry a significant risk of immobility, associated morbidity, and increased mortality³²⁸. Simple falls resulted in 52% of fractures in Edinburgh adults in 2000⁸⁸, and it seems likely that simple falls will continue to contribute to the total fracture workload in Edinburgh, given the predicted rise in the number of elderly adults already discussed³²⁷.

Sporting activity was the second most common cause of fractures in Edinburgh adults, accounting for 14.5% of the total number. Sports-related fractures occur as the result of a wide variety of injury mechanisms, including falls from bicycles, falls whilst running, collisions with other players, torsional and twisting injuries and direct blows from sports equipment. It is likely that patterns of sports fractures will vary between regions depending on the degree of affluence, availability of resources, and the popularity of different sports. North American sports such as baseball, American football and ice hockey are less common than the likes of rugby and field hockey in the UK. However, some sports such as football, Alpine sports (skiing and snowboarding) and the various cycling disciplines (BMX, road cycling, mountain biking) are universally popular. It is likely that the patterns of sports-related fractures presented in this thesis will broadly reflect those from other regions whose distribution of popular sports is similar to that of Edinburgh.

If all injury types are considered then trauma resulting from sporting activity seems common, particularly in regions where sports participation is popular. In a Finnish study from 1978, sports injuries accounted for 10% of presentations to emergency departments and one-fifth of these injuries were fractures³²⁹. Thirty years later, Falvey and colleagues reported that sports injuries made up 14% of emergency department presentations to an Irish teaching hospital. Two-thirds of these injuries affected adults, and the frequency of skeletal fractures ranged from 26-39%, depending on the sport involved³³⁰. In terms of fractures from sport, one report has dealt with a paediatric and adolescent population³³¹, whilst a number of others have dealt with cases of serious injury, including head and facial trauma³³² and spinal injury³³³. Patterns of fractures resulting from all sports participation in an adult

population have received less attention³³⁴, and the many studies have simply analysed individual sporting pursuits.

Sports fractures in Edinburgh most commonly affected the upper limb, in particular the hand and wrist. Previous work from Edinburgh has shown that certain sports are associated with specific patterns of fracture in the hand³³⁵. Figure 3.4 reveals that ankle fractures were more frequently with advancing patient age. Of interest, recent work in the United States has shown that the opposite trend is seen with ligamentous ankle injuries³³⁶. The authors noted ankle sprains to be nine times more common in young adults (15-19 yrs) than in older adults (55-59 yrs). It seems likely that the same injury mechanism producing a sprain in younger age groups is sufficient to cause a fracture in older adults. A similar injury type-related pattern was observed in recreational mountain biking injuries from the Scottish Borders³³⁷, with older riders more frequently suffering fractures or joint dislocations than younger participants.

Football is widely regarded as the world's most popular sport. A study of acute football-related injuries from Finland in 1980 reported that injury to the lower limb was four times more common than the upper limb³³⁸. Fractures accounted for a small proportion of the injuries (11%) reported by the authors, but they occurred more commonly in the upper limb. Football was responsible for over one-third of sports-related fractures in Edinburgh adults. In keeping with the Finnish study, and a report from Edinburgh in 2000³³⁴, the upper limb was more commonly involved (70%) than the lower limb (30%) or pelvis (<1%). The commonest upper limb fractures encountered were those of the finger phalanges, distal radius, metacarpus, scaphoid, clavicle and proximal radius. The propensity for injury to the hand and wrist has previously been described, and is thought to be caused by falling onto the hand, colliding with other players and a direct blow from the football, in roughly equal proportions^{339, 340}.

Common footballing fractures of the lower limb included those of the ankle, metatarsus and tibial diaphysis. The association between football and tibial diaphyseal fractures has been well described³⁴¹⁻³⁴³. In 50% of football-related tibial diaphyseal fractures in the present cohort, the fibula was left intact. This is known to be more common in sports-related injuries compared with non-sport tibial diaphyseal fractures³⁴². There was one avulsion fracture of the anterior inferior iliac spine occurring in a 15 year old schoolboy. Avulsion

fractures, although uncommon, are well recognised sports-related injuries in adolescent athletes with incompletely fused epiphyses²⁸⁵.

Rugby accounted for 14% of sport-related fractures in Edinburgh. Several authors have analysed all rugby injuries, particularly in the Southern hemisphere where both rugby disciplines are popular³⁴⁴⁻³⁴⁶. The rate of injury in rugby varies depending on the level of competition examined (amateur vs. professional) and the frequency of skeletal fractures is reported to range from 6-20%. The results presented in this thesis show that upper limb fractures far outnumbered those of the lower limb in this Edinburgh series, accounting for 83% of rugby fractures. Common fracture types included those of the finger phalanges, metacarpus, clavicle and distal radius. Barton reported that injury to the hand and especially the digits is common in rugby, due to the very physical nature of the sport. Players catch and carry the ball, and tackle other players using the hands, such that two-thirds of all rugby hand injuries tend to be fractures³³⁹.

Skiing and snowboarding are popular in many regions, including Edinburgh, and accounted for 11% of sports-related fractures identified. Japanese researchers have reported that injury rates for skiing and snowboarding are similar, but with improvements in equipment and binding mechanism design fractures from skiing are now much less common. In adult participants, the literature suggests that fractures accounted for only 10% of all skiing injuries^{347,348}. In snowboarding the frequency of fractures is higher. A two-year study performed in the Scottish highlands suggested that fractures represent one-third of snowboarding injuries³⁴⁹. Subsequent Japanese research confirmed the same, and added that two-thirds of these fractures affected the upper limb³⁵⁰. The so-called 'snowboarders fracture' of the lateral process of the talus has been well described^{260,351}. In the UK, where Alpine skiing is only available for a very short season, artificial ski slopes are used. One such slope exists in the Edinburgh area, and Steedman reported on 130 injuries sustained there in 1985³⁵². Half of all injuries were fractures and the upper limb was involved 80% of the time. Unlike football and rugby, where the majority of patients injured were men, skiing and snowboarding fractures in Edinburgh were distributed evenly between the genders. Skiers tended to be older than snowboarders. Of note, fractures suffered whilst skiing or boarding on artificial matting resulted exclusively in upper limb injury, affecting the finger phalanges, metacarpus and distal radius, presumably resulting from a fall onto the outstretched hand. Alpine skiing and snowboarding resulted in a similar pattern of upper limb injury, with fractures affecting the distal radius, finger phalanges and clavicle.

Cycling is popular in many different parts of the world and a wide variety of disciplines exist, including mountain biking, road cycling and BMX. Acute fracture from cycling is most often related to falling from the bicycle. The cycling disciplines accounted for 10% of sports-related fractures, and no discernible difference was identified between the disciplines in terms of the patterns of skeletal injury encountered. The majority of fractures affected the upper limb, with fractures of the clavicle, distal radius and proximal radius most common.

Almost three-quarters of cycling fractures were sustained from mountain biking, and predominantly affected young men. Mountain biking has grown steadily in popularity since the late 1970s, and injury rates vary depending on the level of competition and the discipline studied (*e.g.* cross-country vs. downhill). In 1995, a study of 6,000 competitive riders reported 31 acute injuries (0.5%), with fractures accounting for 7-15%. Injury rates in recreational mountain biking seem to be much lower, although there are many difficulties in obtaining complete data. The frequency of skeletal fractures in injuries from a popular Scottish mountain biking centre was 37%, with two-thirds affecting the upper limb³³⁷.

One-quarter of cycling fractures was suffered by road cyclists; again predominantly men, but with a higher average age. There is little available information on acute road cycling injuries, and recent interest has focused on overuse and other chronic conditions³⁵³. The road cycling discipline may be associated with a lower risk of falling than in mountain biking or BMX, as riders do not negotiate jumps, ramps or steep off-road downhill sections. More likely, the limited number of reports is related to difficulties in defining causation for road cycling injuries. Injuries sustained from collisions with other road users (motor vehicles, motorcycles, other cyclists) may be termed 'sports-related', but equally may be described as 'road traffic accidents'. Deciphering the differences between cycling on roads recreationally, and cycling on roads for commuting purposes is a challenge for injury epidemiologists.

A small number of BMX fractures were suffered by young men. BMX cycling became extremely popular in the 1980s. In 1989, a study of 1,000 competitive BMX participants reported acute injury in 6.3% of riders. Fractures accounted for 6.7% of these injuries, and three-quarters affected the upper limb³⁵⁴. As with the Alpine sports, the cycling disciplines can be associated with high energy transfer, depending on the speed or height attained prior to falling. A number of relatively high energy injuries were seen in this study. One distal

tibial fracture resulted from a BMX accident. From mountain biking, one lateral compression pelvic fracture was identified. From road cycling, one proximal femoral fracture, a femoral diaphyseal fracture and a scapular body fracture were sustained. Despite early concerns regarding the safety of mountain biking and other cycling disciplines, these results and others³³⁷ would suggest that high energy or catastrophic injury is no more common than in many other popular sports.

In contrast, two sports in this study (horse riding and motocross) were associated with a higher proportion of significant lower limb or pelvic injury than the other popular sports discussed above. Of the 25 fractures sustained as a result of horse riding, two involved the pelvis (one acetabular fracture and one iliac blade fracture), two affected the tibial plateau fractures, two involved the tibial plafond and one the talar body. Of note, the median age of horse riding patients was 39 years (*cf.* 25 yrs for all sports) and 85% of those affected were women. Significant orthopaedic injury from equestrian pursuits has been previously reported. A three year study from North America found that 28% of acute horse riding injuries resulted in bony injury, and approximately one-fifth of these fractures involved the skull, spine or pelvis³⁵⁵. Motocross caused 24 fractures, of which three involved the tibial diaphysis, three affected the tibial plafond, and one represented a lateral compression fracture of the pelvis. Motocross is known to be a high risk sport. A previous report detailing ten years of acute injuries in competitive European motocross riders revealed that motocross was second only to motorcycle racing in terms of injury incidence³⁵⁶. The authors reported that 25% of injuries were fractures, and that one in ten fractures involved the spine, pelvis or hip³⁵⁶.

Direct blow fractures included those resulting from intentional direct blows (most commonly 'punching injuries'), unintentional direct blows, or accidental crushing or compressive injury. A popular and commonly encountered example of one such described direct blow fracture is the 'boxer's fracture' – a fracture of the fifth metacarpal neck suffered by punching with the clenched fist¹⁸⁸. Interestingly, it is said rarely to occur as a result of the sport of boxing³⁵⁷. Intentional direct blows were seen almost exclusively in young men, and 90% involved the metacarpus, most often the 4th or 5th metacarpal bones. The greatest proportion of 5th metacarpal direct blow fractures affected the midshaft or base (67%), which is perhaps surprising given the association with head or neck fractures with punching injuries. When analysing all 5th metacarpal head and neck fractures, 32% were *not* due to a

punching injury, suggesting that the term 'boxer's fracture' is probably an inappropriately cast aspersion in approximately one in three cases.

One unexpected mode of injury, causing 32 fractures in predominantly older female patients, was the direct blow collision with domestic pets. Direct blows from dogs caused five fractures of the ankle, four of the tibial plateau, three tibial diaphyseal fractures, two hip fractures and a distal femoral fracture. Upper limb fractures from dogs included five of the distal radius, three of the proximal humerus and two of the proximal radius, presumably resulting from a fall onto the upper limb as a result of the collision. This unusual pet-related hazard has been recognised previously. Lindstrom and colleagues found that interaction with dogs and cats accounted for 1.4% of injuries in a two-year period in Northern Sweden, with the majority of attendances due to bites and scratches³⁵⁸. Kurrle *et al* further commented on the 'perils of pet ownership' in 2004, with their anecdotal Christmas offering to the Australian Medical Journal³⁵⁹. They reported on fall-related fractures in the elderly and found that tripping over pets was particularly hazardous. A more serious report from the United States suggested 86,000 fall-related injuries per year occurred between 2001 to 2006 as a result of cats and dogs. Dogs accounted for 88% of cases, and women were injured more often than men.

Improvements in automobile design and stricter seatbelt, speeding and alcohol legislation have contributed to a reduction in road traffic accident (RTA) related morbidity and mortality in many countries³⁶⁰. Despite this, RTAs remain one of the leading causes of death and injury, particularly in young adults. According to Scottish government sources, a total of 16,063 road casualties were reported in Scotland in 2007. Fatalities accounted for 282 (<2%) of those involved, with 2,316 (14%) suffering 'serious injury'³⁶¹. This study of 545,000 Edinburgh residents revealed 360 fractures occurring as a result of RTAs. The total number of RTA fractures in Edinburgh is remarkably similar to that identified by Court-Brown and Caesar⁸⁸ in 2000 (370 injuries). The amount of energy involved during a RTA will vary depending upon the speed at which the collision takes place, and the direction and magnitude of forces acting upon the skeleton. The average number of RTA fractures per injured patient was 1.31 (Table 3.11), and was found to be greatest in motorcyclists (1.46) and pedestrians (1.45), followed by vehicle occupants (1.36) and pedal cyclists (1.11). The analysis of all RTA subgroups found that 60% of patients suffering a fracture of the pelvis would have fractures elsewhere.

A previous study from the emergency department in Edinburgh, and published in the early 1990's, found that 14% of all RTA injuries occurred in motorcyclists³⁶². The present study has shown that motorcyclists account for a larger proportion of the total RTA injured cohort (32%) if only acute fractures are considered. The vast majority were young men aged less than 40 years. Fifteen percent of motorcycling fractures were open injuries, and two-thirds of these were classified as Gustilo and Anderson¹¹² grade 3. Eleven percent of RTA fractures were suffered by occupants of vehicles. Previous research utilising Scottish trauma data suggested that vehicle passengers are at higher risk of injury than vehicle drivers³⁶³, but no discernible difference in fracture patterns was identified between these groups mainly due to the small numbers (n=43) encountered in the 12 month period of study.

For the purposes of this study, all falls from approximately six feet (1.8 m) or greater constituted 'falls from height'. The severity of this type of injury is known to be related to the height of the fall, with a high proportion of visceral injuries apparent at falls from six metres or more^{364, 365}. Falls from greater than 30 metres usually result in death³⁶⁶, and severe head injury is also known to correlate with mortality^{367, 368}. The pattern of skeletal injury varies with the height of the fall and subsequent energy transfer, with a higher frequency of pelvic and multiple fractures as the distance fallen increases³⁶⁵. It is important to note that in this study patients were included only if they survived long enough to be referred to the orthopaedic services. Additionally, skull, maxillofacial, rib and spinal fractures were not recorded. The falls from height results presented in Section 3.3 will therefore underestimate the total number of skeletal injuries sustained by this patient group.

Nonetheless, falls from height were associated with the highest frequency of fractures to the pelvis (9.2%) when compared to all other modes of injury. The frequency of lower limb fractures (50.2%) was also higher than most other injury modes. A number of similarities were seen between those suffering fractures from height and patients involved in RTAs. Three-quarters of patients were men, and the age-related distribution of patients was virtually identical (Table 3.8). The frequency of multiple fractures from height varied between different patient groups, just as in patients with RTA fractures. In patients with a fracture of the pelvis, 70% had suffered fractures elsewhere. In patients whose index fracture involved the lower limb, 22% sustained other fractures.

Relatively little has been written in relation to falls down stairs. Unlike free falls, which can be categorised according to the height of the fall, it is not possible to classify falls down

stairs in the same way. The way that a patient falls, slides or tumbles down stairs is likely to influence the pattern of injuries sustained, as is the ability of the patient to protect themselves from injury. The literature does show that some falls down stairs can cause severe injury, particularly in elderly patients, and one study has shown that 51 patients in south-east Scotland died as a result of this injury mode between 1992 and 1997³⁶⁶. Similarities can be drawn between the age-related distribution of fractures from falling down stairs, and those sustained by a simple fall from standing. They are both examples of Buhr and Cooke's J-shaped curve⁸⁴, or Court-Brown and Caesar's type F unimodal older male and female distribution curve⁸⁸, although patients with fractures from falling down stairs were on average slightly younger than those suffering a simple fall fracture.

Table 3.7 lists the different individual fracture types identified in Edinburgh as a result of this epidemiological study. Arranged in order of decreasing incidence, the ten most common fractures types affecting adults in Edinburgh were those of the distal radius, proximal femur, metacarpus, finger phalanges, ankle, proximal humerus, metatarsus, clavicle, proximal radius and carpus. In 2000, Court-Brown and Caesar⁸⁸ found a similar pattern of common fractures and the incidences of these injuries are shown in Table 5.2. Singer *et al*, in their report on adult fractures⁸⁹, did not present details for all individual fracture types. Therefore the data presented in Table 5.2 is incomplete for the 1992 to 1993 time period.

Present series 2007-2008		Court-Brown and Caesar 2000		Singer <i>et al</i> ** 1992-1993**	
Fracture type	Incidence	Fracture type	Incidence	Fracture type	Incidence
Distal radius	20.6	Distal radius	19.5	Distal radius	20.3
Proximal femur	15.1	Metacarpus	13.0		
Metacarpus	13.5	Proximal femur	12.9	Proximal femur	14.6
Finger phalanges	12.4	Finger phalanges	10.7		
Ankle	11.6	Ankle	10.1	Ankle	12.0
Proximal humerus	9.3	Metatarsus	10.1		
Metatarsus	7.9	Proximal humerus	6.3	Proximal humerus	6.0
Clavicle	5.1	Proximal forearm*	5.6		
Proximal radius	4.9	Toes	4.0		
Carpus	3.8	Clavicle	3.7	Tibial shaft	3.1

Table 5.2 The incidence (n/10,000/yr) of the most commonly encountered fractures occurring in Edinburgh adults, in the present series, in 2000⁸⁸, and in 1992 to 1993⁸⁹.

*Combined incidence of proximal radius and proximal ulna fractures. **Data from 1992 to 1993 are incomplete, as only those fracture types presented in the report by Singer *et al* are included.

In the 1950s in Oxford, Buhr and Cooke⁸⁴ noted the commonest fracture types to be those of the finger phalanges, closely followed by those of the 'distal radius & ulna', and then the

ankle. Tibial shaft fractures were only slightly less common than ankle fractures. Of particular note, fractures of the 'distal radius & ulna' numbered twice as many as those of the hip. Hip fractures were only the tenth most common fracture type encountered, which represents a very different pattern from that seen nowadays. By the early 1980s, Donaldson *et al*⁸⁶ in Leicester, using fracture ascertainment methods akin to those used in Edinburgh, found hip fractures to number second only to 'distal forearm' fractures, followed by fractures of the ankle, metacarpus, and metatarsus. Tibial shaft fractures were the eighth commonest fracture type reported.

Other researchers have used non-orthopaedic sources of fracture data to report the commonest fracture types. Sahlin⁹⁰ used emergency department fracture data to estimate adult fracture patterns in Trondheim, Norway, in the mid 1980s. He found fractures of the forearm to outnumber those of the foot, 'carpus & metacarpus', hip, and fingers. Johansen *et al*⁸⁷ also used emergency department data to determine patterns of adult fractures in Cardiff in the mid 1990s and reported the commonest fracture groups to be 'wrist & forearm', 'fingers & hand', 'foot & toes', hip, then ankle. Finally, van Staa and colleagues⁹⁴ used the GPRD as a data source and stated the commonest adult fractures to be those of the 'radius & ulna', carpus, 'tibia & fibula & ankle', foot, then 'femur & hip'.

The fracture type groups used by non-orthopaedic researchers to categorise fractures bear little resemblance to the clinically relevant categories used in orthopaedic research. This is probably best explained as an attempt by researchers to minimise the coding error inherent in systems such as the GPRD that use many generic fracture codes. Indeed, van Staa *et al* explained that a limitation of their study was the use of such non-specific coding terms⁹⁴. One example, 'femur fracture', could in fact relate to a fracture of the femoral head, the hip, femoral shaft, or distal femur. The most appropriate way of categorising fractures in future epidemiological research is to group these injuries according to how they are described anatomically, and treated clinically, by the clinicians involved in their management. In that way, epidemiological fracture data may be used to help determine trends in fracture type incidence, and plan services accordingly.

A fracture of the distal radius was the commonest single fracture type encountered during the study period. In comparison with the published results of Singer *et al* in 1992⁸⁹, it would seem that the overall incidence of these fractures in Edinburgh has changed very little. Previous studies have reported the incidence of distal radial fractures from various countries,

including Japan where the rate is 11/10,000/yr, to Norway where the incidence is considerably higher (38/10,000/yr)^{134, 165, 176, 177}. It is likely that the some of the differences will relate to the methodology employed in capturing fracture data (as discussed above), but many other factors are thought to be involved. In keeping with these previous reports, the age-adjusted incidence of distal radial fractures in Edinburgh women in the current study (27.7/10,000/yr) was more than twice that of men (13.0/10,000/yr), and was found to increase dramatically in post-menopausal age groups.

A cadaveric study of 1,000 specimens with insufficiency fractures in male and female skeletons noted them to be due to age-related bone loss and all of its risk factors³⁶⁹. The literature suggests that elderly men and women share common risk factors for upper limb fractures, and that decreased bone mineral density is the most important influence¹⁷⁰. In this series of 1,100 distal radial fractures, a progressive rise in their age-adjusted incidence was noted in men as well as women. Many studies support the idea that distal radial fractures can no longer be considered solely a disease of elderly women^{370, 371} and suggest that hormonal factors are important in elderly patients of both genders³⁷². Age-related bone loss is of course far more pronounced in women, predominantly due to the effect of the menopause. Interestingly, a recent study examining 108 postmenopausal patients followed over 15 years has shown that the strength index in the distal radius decreases proportionally with falling oestradiol levels³⁷³. The authors noted that a decrease in strength index of one standard deviation conferred a 3.8 times increase in relative risk of distal radial fracture. An increased risk of more severe fractures has also been shown with deteriorating bone density³⁷⁴ which may explain the frequency of the more severe fractures in older women.

In this series, AO type A fractures (60%) and type C (24%) fractures were more commonly encountered than type B fractures (16%). Both types A and C fractures are considered the metaphyseal injury types, and 73% of these injuries occurred in women. The median age of patients suffering type C intra-articular fractures was 63 years, proving that these injuries occur predominantly in postmenopausal women, and not in young men following high energy trauma as is often assumed. The common fracture subtypes A3.2 and C2.1, which can be considered the classic Colles type fractures, accounted for 39% of all distal radial fractures identified. Metaphyseal comminution leading to metaphyseal instability is a common feature of these two fracture subtypes, and the treatment of these injuries may be one of the biggest challenges confronting the orthopaedic trauma services in Edinburgh in

the future, particularly if the proportion of elderly adults in the population increases as predicted.

The second most common fracture type encountered in Edinburgh adults was that of the proximal femur, and 96% of these were hip fractures. Hip fractures are common orthopaedic injuries and occur predominantly in the elderly. The incidence of hip fractures in Edinburgh adults has shown a marginal increase from 14.6/10,000/yr in 1992 and 1993⁸⁹ to 15.1/10,000/yr in 2007 to 2008, but as life expectancy increases worldwide many authors expect the incidence of proximal femoral fractures to increase. Dennison *et al* analysed current trends of hip fracture in the UK³⁷⁵. Their results have suggested that hip fracture numbers will increase from 46,000 in 1985 to 117,000 in 2016. However, a small number of European studies analysing hip fracture incidence over time have failed to show the predicted rate increase^{189, 200, 376-378}, and one Swiss study has even reported a slight decrease in hip fracture incidence in women³⁷⁹. The incidence of hip fractures in men in Edinburgh has risen from 6.8/10,000/yr as reported by Singer *et al*⁸⁹ to 8.6/10,000/yr in the present series. The incidence in women appears to have fallen slightly, from 21.7/10,000/yr to 20.9/10,000/yr, although the rate difference is small. It has certainly not increased, as Dennison *et al* had predicted³⁷⁵.

Significant differences in hip fracture incidence exist between races, and unlike fractures of the hand, carpus, and distal radius, these differences are much less likely to relate to methodological difficulties. Koh *et al*, found increased rates of fracture in Singapore Chinese, compared to patients of Indian or Malay decent³⁸⁰. Ross *et al* found increased hip fracture incidence in White Americans, compared to Hawaiian Japanese and native Japanese populations³⁸¹. Lauderdale *et al* also found hip fracture risk to be highest in elderly White races in the United States, when compared with elderly Hispanic and Black populations³⁸². This research group also showed that fracture risk was determined by the patients' region of residence in early life, rather than where they had chosen to settle in retirement³⁸³.

The Mediterranean Osteoporosis Study (MEDOS) analysed a large number of European patients with hip fractures in order to identify risk factors^{384, 385}. The authors highlighted low body mass index, low activity levels, reduced exposure to sunlight, increased consumption of alcohol and tobacco, and a late menarche as important factors in the aetiology of these injuries. Factors such as these, and perhaps minor errors related to study methodology and fracture coding, are likely to explain the reported differences in hip fracture incidence

between regions. While some studies have concentrated on hip fracture incidence in elderly patient groups, the rates shown in Table 5.3 are from studies where all adult age groups have been included in the analysis.

Author	Country	Incidence (n/10,000/yr)		
		Male	Female	Overall
Bergstrom ³⁸⁶	Sweden	31.7	62.5	-
Karacic ³⁸⁷	Croatia	-	-	47.0
Chevalley ³⁷⁹	Switzerland	15.3	45.5	-
Koh ³⁸⁰	Singapore	15.2	40.2	-
Silveira ³⁸⁸	Brazil	13.0	27.7	27.1
Jequier ³⁸⁹	Switzerland	8.4	24.1	16.7
<i>Current</i>	<i>UK</i>	<i>8.6</i>	<i>20.9</i>	<i>15.1</i>
Icks ³⁷⁶	Germany	-	-	14.1
Court-Brown ¹³²	UK	-	-	12.9
Melton ³⁹⁰	USA	8.2	11.8	10.4
Lee ³⁹¹	Malaysia	-	-	7.0

Table 5.3 Studies reporting hip fracture incidence in adults, in order of decreasing incidence.

Fractures and fracture dislocations involving the hand are some of the most frequently encountered orthopaedic injuries. In the 1950s, Buhr and Cooke⁸⁴ noted finger fractures to be the commonest fracture type encountered. In this study, fractures of the metacarpus and phalanges were the third and fourth most common fracture types encountered, with incidences of 13.5/10,000/yr and 12.4/10,000/yr, respectively. Hand fractures appear to be an affliction of young adults, as patients aged 50 years or less accounted for 80% of the hand fracture population. Direct violence (punching injuries, other direct blows, crush and bite injuries) was responsible for 44% of hand fractures, a larger proportion than in any other fracture type group. Section 3.3 analysed all direct blow fractures, and found that the metacarpus is most commonly injured region following a punching injury, whereas the phalanges are most commonly involved in unintentional direct blow injuries.

It must be emphasised that the majority of complex combined hand injuries, cases of 'massive hand trauma', and all injuries requiring soft tissue coverage or flexor tendon repair were treated in a separate institution by the plastic surgical services. These cases were therefore not included in the present analysis. Nevertheless, the overall incidence of hand fractures in the present series is similar to that of the large series from Canada¹⁸³, where Feehan and colleagues reported an incidence of 36/10,000/yr and noted a predominance of young male patients. They included severe hand trauma and also analysed fractures in children, but they made use of emergency department data. The results from Chapter 2

suggest that ED data overestimate finger phalanx and metacarpal fractures by approximately 15% and 20%, respectively. After adjustment, the Canadian incidence would be approximately 28/10,000/yr, which is comparable to the incidence from this series (25.9/10,000/yr).

Ankle fractures were the fifth most common fracture type identified. The literature suggests that, like hip fractures, the incidence of ankle fractures also varies between countries and Table 5.4 outlines the reported incidences from various studies.

Author	Year	Country	Incidence (n/10,000/yr)		
			Male	Female	Overall
Daly <i>et al</i> ²⁵⁸	1979-81	USA	20.7	16.5	18.4
Johansen <i>et al</i> ⁸⁷	1994-95	England	14.7	13.7	14.2
Court-Brown <i>et al</i> ²⁵⁴	1988-90	Scotland	13.2	11.2	12.2
Singer <i>et al</i> ⁸⁹	1992-93	Scotland	12.5	11.5	12.0
<i>Current</i>	2007-08	Scotland	11.3	11.8	11.6
Sahlin ⁹⁰	1985-86	Norway	-	-	11.0
Bengner <i>et al</i> ³⁹²	1980-82	Sweden	-	-	10.7
Court-Brown and Caesar ¹³²	2000	Scotland	-	-	10.1
Brinker and O'Connor ⁹³	1998-2000	USA	-	-	8.9

Table 5.4 Studies reporting the incidence of ankle fractures in adults, arranged in order of decreasing incidence.

In the USA, Daly *et al* reported an overall incidence of 18.4/10,000/yr over a three-year period in Rochester, Minnesota²⁵⁸. Of note, the authors included children in their analysis of 314 fractures. They commented on the much higher rates of ankle fracture noted in their population than in other European studies. Johansen *et al*⁸⁷ reported a rate of 14.2/10,000/yr in 1994 and 1995 when calculating the incidence of ankle fractures in adults. It must be stressed that these studies both used ED numerator fracture data to calculate incidence. The results from Section 2 have shown that the positive predictive value (PPV) of an ankle fracture diagnosis in the ED is 75%. Therefore, it is likely that Daly's and Johansen's results overestimate ankle fracture incidence.

An epidemiological study of 1,500 ankle fractures in Edinburgh adults was carried out between 1988 and 1990²⁵⁴. The authors used data obtained from an established trauma database, collected by orthopaedic surgeons, and reported an overall incidence of 12.2/10,000/yr. A few years later in Edinburgh, Singer *et al*⁸⁹ noted ankle fracture incidence to have fallen to 12.0/10,000/yr. This trend appears to have continued, with a further fall in incidence to 11.6/10,000/yr in this series. Prior to this, the literature was concerned with the

apparent increase in ankle fracture incidence. In the 1950s, Buhr and Cooke⁸⁴ noted ankle fractures to be as common as fractures of the distal radius, although they were unable to give an estimate of the overall rates of ankle fracture. A number of reports have documented the gradual increase in ankle fracture incidence since the 1950s, in keeping with the changing population demographics of many countries^{258, 392, 393}. Fracture data in Edinburgh was not collected before 1988 and it is therefore not known whether ankle fracture incidence has increased prior to the observed decline in fracture rates observed since 1988. However, Bengner and colleagues reported an increase in ankle fracture incidence over a thirty year period in a Swedish population, from 6.5/10,000/yr (1950 to 1952) to 10.7/10,000/yr (1980 to 1982)³⁹². They found the greatest increase in age-adjusted incidence to occur in women aged 65 years or more.

Kannus *et al* reported on the incidence of ankle fractures in older Finnish adults, aged 60 years or more³⁹³. They too found a dramatic increase in elderly female incidence between the 1970s (6.3/10,000/yr) and 1980s (16.8/10,000/yr), but thereafter found the rate to stabilise. The same research group have reported a similar pattern with other skeletal injuries in Finland, including hip fractures³⁷⁷. Karagas and colleagues documented the gender-related differences in ankle fractures in the elderly United States Medicare population (aged 65 to 89 yrs) from 1986-90³⁹⁴. They found the rate in elderly women (22.6/10,000/yr) to be 240% higher than that seen in elderly men (9.4/10,000/yr). The results from this study confirm that ankle fractures are uncommon in elderly men, and display a distinct type A distribution. They occur predominantly in young men and older women, and for the first time in the literature it seems the overall incidence in women is now higher than that identified in male patients.

Fractures of the proximal humerus are one of the most common fractures seen in the elderly, and they were the sixth most common fracture type identified and presented in this thesis. Court-Brown *et al* reported on proximal humeral fractures in the Edinburgh population from 1992 to 1996¹³⁷. A comparison of the age-adjusted incidences of proximal humeral fractures from the present study, with that presented by Court-Brown *et al*, is shown in Table 5.5 (next page). The method of data collection used in both studies is comparable, yet over a period of 13 years there has been a marked increase in fracture incidence. The change is most pronounced in the elderly, and particularly in men, although it must be noted that total fracture numbers in the elderly groups remain small.

Age group (yrs)	1992-1996	2007-2008	1992-1996	2007-2008
	Male incidence	Male incidence	Female incidence	Female incidence
10-19	1.1	-*	0.8	-*
20-29	5.0	2.6	0.4	0.2
30-39	1.5	3.0	0.4	1.2
40-49	2.0	4.2	2.0	5.1
50-59	2.8	6.1	4.5	12.0
60-69	3.4	10.8	9.6	20.6
70-79	5.8	12.7	18.8	38.3
80-89	10.9	20.7	26.0	55.2
90-99	15.9	86.9	13.9	74.6

Table 5.5 The age-specific incidences of proximal humerus fractures occurring in Edinburgh adults from 1992 to 1996¹³⁷, compared with the present cohort of Edinburgh adults sustaining injury from 2007 to 2008. The incidence rates shown are ‘n/10,000/yr’. *Data for patients aged 10-14 years were not collected.

Metatarsal fractures were the seventh commonest fracture type seen. Relatively little has been written about these injuries, with the exception of fractures affecting the 5th ray. The literature suggests that 5th metatarsal fractures can be divided into proximally based fractures and distal fractures^{395,396}. Proximally based injuries can be further divided into three zones (Fig. 5.1). Zone I injury (n=157, 54.7%) at the 5th metatarsal base usually represents an avulsion fracture. Hindfoot inversion causes tension along the lateral band of the plantar aponeurosis which inserts into the plantar aspect of the metatarsal tubercle. Occasionally, a direct blow to the area can result in a similar fracture pattern. Zone II injuries (n=41, 14.3%) occur at the junction of the proximal metatarsal metaphysis and diaphysis and are termed Jones fractures (named after Sir Robert Jones, who described the injury in 1902³⁹⁷). They are caused by forced adduction of the forefoot.

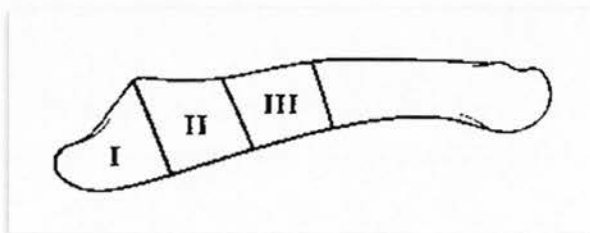


Figure 5.1 The three fracture zones of the proximal 5th metatarsal. Zone I fractures represent an avulsion injury, zone II fractures occur at the metaphyseal-diaphyseal junction, and zone III fractures represent proximal diaphyseal fractures.

Zone III fractures (n=21, 7.3%) have been described as proximal diaphyseal stress fractures, and one report suggests they are mainly seen in athletes³⁹⁸. In keeping with this finding, 47.6% (n=10) of zone III fractures resulted from sport. Notably, sport accounted for only

9.8% of 5th metatarsal fractures overall. Distal fractures (n=68, 23.7%) involve the remainder of the 5th metatarsal. O'Malley reported that a rotational force applied to the plantarflexed and axially loaded forefoot produced this fracture pattern³⁹⁹.

The eighth commonest fracture type was that of the proximal radius. In 1954, Mason reported fractures of the proximal radius as occurring almost exclusively in young men⁴⁴. This study, in keeping with others¹⁵⁰⁻¹⁵³, has found that the incidence is similar in men and women, but the gender-related distribution curves for isolated injuries (Fig. 3.25) confirm that men and women present at different ages. The peak age-related incidence in women occurred 20 to 30 years later than that in men. This gender-related difference seems to be more apparent in the analysis of 'combination' elbow fractures, where two-thirds occurred in women. Although the numbers analysed were small (15 patients), the median age of women (66 yrs) was greater than that of men (42 yrs).

Radial neck fractures were outnumbered by those of the radial head by approximately 2:1. Neck fractures presented in patients of similar age and gender, and an equivalent proportion resulted from high energy trauma, yet a far greater proportion of radial head fractures were associated with more complex injury patterns. Ten percent of radial head fractures were classified as Mason type 3 or 4, compared with 1% of radial neck fractures. Of the 15 proximal radial fractures found to occur as part of combination elbow fractures, 14 of 15 involved the head.

The literature suggests that the frequency of associated soft tissue and / or osseous injury at the time of proximal radial fracture ranges from 12% to 39%^{151, 153}. In this series, 5.8% of proximal radial fractures occurred in combination with an elbow dislocation and 5.3% occurred with ipsilateral elbow fractures. The frequency of associated (non-elbow) fractures resulting from the same injury episode was 12.3%.

Fractures of the clavicle were the ninth most common fracture type seen in Edinburgh adults. The distribution of fractures from the present series differs slightly from that described by Robinson 13 years previously²⁸, despite the use of identical methods for capturing fracture data. Robinson reported an average patient age of 33.6 yrs, a frequency of type 3 lateral one-fifth fractures of 28%, and an overall fracture incidence of 2.9/10,000/yr from 1988 to 1994. Of note, Robinson included patients aged 13 and 14 years of age. This series of 280 consecutive fractures in patients aged 15 yrs and older demonstrated an average age of 42.5

yr, a 36% frequency of type 3 fractures and overall incidence of 5.1/10,000/yr. If the inclusion criteria are modified, and 13 and 14 year olds are included in the present analysis, the average age is 39.4 yrs. The incidence of clavicle fractures in the Edinburgh population seems to have increased since Robinson's report. A greater proportion of older adults have been affected and a greater number of fractures involve the lateral one-fifth. Given the inherently greater risk of delayed and non-union in type 3 fractures, this trend has potential implications for the future management of clavicle fractures in Edinburgh.

Carpal fractures were the tenth most common fracture type identified in this study. The overall incidence of carpal fractures was 3.8/10,000/yr and represents a small increase from that reported in Edinburgh in 2000⁸⁸ when the incidence was 3.0/10,000/yr. Of note, Donaldson et al also used orthopaedic numerator fracture data and found the incidence of carpal fractures to be 3.1/10,000/yr. In contrast, van Staa and colleagues⁹⁴ used GPRD numerator data to report carpal fracture incidence as 18.0/10,000/yr.

The majority (69%) of carpal fractures in the present series involved the scaphoid. Undiagnosed and untreated scaphoid fractures have poorer outcomes due to delayed union or non-union at the fracture site¹⁷⁹ and radiological studies have reported that up to 25% of scaphoid fractures are 'occult', *i.e.* missed following initial radiographs⁴⁰⁰⁻⁴⁰³. As a consequence, many patients are diagnosed as having suffered a 'possible' or 'clinical' scaphoid fracture at the point of first contact with the healthcare services in order to reduce the number of missed diagnoses. This has implications for epidemiological research. It is difficult for researchers to accurately define the incidence of these injuries, particularly when the research methodology employed utilises emergency department data.

Author(s)	Country	Methodology	Incidence (n/10,000/yr)		
			Male	Female	Overall
Current	UK	Orthopaedic & Radiology	4.0	1.5	2.7
Court-Brown ¹³²	UK	Orthopaedic & Radiology	-	-	2.4
Hove, 1999 ⁴⁰⁴	Norway	Orthopaedic & Radiology	-	-	4.3
Larsen, 1992 ⁴⁰⁵	Denmark	Orthopaedic & Radiology	3.8	0.8	2.2
Wolf <i>et al</i> , 2009 ⁴⁰⁶	US (military)	ED data	12.9	7.9	12.1
van Tassel, 2010 ⁴⁰⁷	US	ED data (NEISS)	-	-	0.15

Table 5.6 Studies reporting scaphoid fracture incidence. The methodology employed is also shown (*ED* = emergency department; *NEISS* = national electronic injury surveillance system).

Table 5.6 (previous page) highlights the range of reported scaphoid fracture incidence rates in the literature. The incidence in the present series was 2.7/10,000/yr and was higher in men than in women. This rate is consistent with published studies from Norway⁴⁰⁴, Denmark⁴⁰⁵ and Edinburgh¹³² where a similar research methodology has been employed. Compare these findings with those of the two studies carried out in the United States. Wolf *et al* reported on a young active military population⁴⁰⁶, while van Tassel *et al* used the NEISS (national electronic injury surveillance system) to report on a representative sample of the general population⁴⁰⁷. The authors of both studies were unable to distinguish 'true' from 'suspected' scaphoid fractures due to the inherent coding errors introduced by use of emergency department data. The reported incidence in the former study was *eighty* times that of the latter and simply serves to underline that this methodology should not be used to investigate the patterns of scaphoid fractures.

5.3 What constitutes a 'fragility fracture'?

Osteoporosis is a systemic skeletal disease characterised by low bone mass and deterioration of bony architecture, with a consequent increase in bone fragility. The clinical consequence of osteoporosis is skeletal fracture, and some reports have suggested that the number of fractures occurring in osteoporotic bone, termed fragility fractures, is increasing^{408, 409}. Furthermore, the problem of sustaining low energy fragility fractures seems to be self-perpetuating: in one study of 22,000 patients with a low energy fracture of the wrist, hip, proximal humerus or ankle the risk for future fractures was four times that of unaffected individuals⁴¹⁰.

In apparent contrast to the fears of an increasing burden of fragility fractures, a recent review article has suggested that the incidences of many specific fragility fractures in the USA, the UK and other Northern European countries has now stabilised and may even be declining in some instances⁴¹¹. This has occurred following a dramatic increase in fragility fracture incidence in the latter half of the 20th century.

The best example of this stabilising trend, and perhaps the best studied, is the incidence of hip fractures. Reports from Norway, Finland and Germany have all shown a stabilisation of the age-adjusted incidence of hip fractures in adults since the 1990s^{189, 200, 376, 377}. The results presented in Section 3, and compared with historical Edinburgh data, have failed to illustrate any rise in the overall incidence of hip fractures in Edinburgh since 1992. The incidence in men has increased by approximately 25% (6.8/10,000/yr vs. 8.6/10,000/yr), but this has been offset by a small decrease in the incidence in women. Trends in the incidence of distal radial fractures have received less attention, but age-adjusted rates in Sweden, the Netherlands and Denmark appeared to reach a peak in the 1980s and have since gently declined⁴¹¹. Perhaps the true trend for future fragility fractures lies somewhere between these two theories. As the proportions of elderly adults in the Scottish and UK populations grow, the total number and range of fracture types encountered in patients with poor bone quality may increase. Although the age-adjusted incidence of the traditionally considered fragility fractures may remain the same, orthopaedic clinicians may see the emergence of 'new' fragility fracture types. Indeed, some fracture types not normally associated with poor bone quality may in years to come be considered as fragility fractures.

A review of the literature reveals there has already been some debate as to which fracture types should be considered fragility fractures. The definition of 'fragility' suggests that fractures occurring under conditions of normal physiological loading should be included in this category. Ordinarily, skeletal injury will not result from a simple fall from a standing height, and previous definitions have included all fractures that result from this low energy injury mode. Kanis *et al* have defined fragility fractures as those occurring at a site associated with low bone mineral density, and whose incidence rises after the age of 50 years⁴¹². Applying this definition, Johnell and Kanis formulated a list of fragility fractures in their review of the subject in 2005³²⁶:

- Vertebra
- Tibia & fibula (in women only)
- Ribs
- Clavicle
- Sternum
- Scapula
- Pelvis
- Humeral shaft
- Hip
- Distal radius
- Femoral shaft

Buhr and Cooke were the first to produce fracture distribution curves in 1959, and their J shaped curve showed a unimodal distribution affecting older adults, referred to as the 'post wage-earning' curve⁸⁴. They too noted fractures of the proximal humerus, humeral diaphysis, proximal femur and pelvis to be fragility fractures.

Table 5.7 (next page) presents the various fracture types identified in this large cohort of Edinburgh adults and arranged in order of decreasing patient age. Fracture types might be considered as fragility fractures if they display the following five characteristics:

- They display a greater overall affected patient age distribution than other fractures
- They involve a high proportion of those aged over 60 years
- They involve a high proportion of those aged over 80 years
- They occur more frequently in women than in men
- They result predominantly from low energy trauma

	(n)	Median age (yrs, IQR)	60+ yrs (%)	80+ yrs (%)	Gender ratio (M/F)	Simple fall (%)	Curve type
Proximal femur	821	83 (76-88)	94.4	64.5	27/73	90.2	F
Pelvis	128	77 (43-86)	70.1	45.7	28/72	60.3	E
Femoral diaphysis	96	75.5 (59.5-85)	75.0	39.6	44/56	63.5	G
Distal humerus	46	71.5 (38-83)	63.8	34.0	35/65	73.9	E
Proximal humerus	502	70 (55-80)	68.7	26.1	31/69	77.6	F
Distal femur	36	65 (45-86)	58.3	33.3	36/64	72.2	E
Patella	55	64 (42-72)	60.0	20.0	33/67	72.7	A
Distal radius	1,124	62 (37-76)	53.7	18.4	30/70	66.7	G
Humeral diaphysis	69	60 (46-78)	50.7	20.3	48/52	62.3	F
Proximal ulna	66	59 (36-75)	50.0	15.2	47/53	65.2	G
Proximal radius & ulna	30	58 (36-82)	50.0	25.0	33/67	66.7	A
Proximal tibia	82	58 (34-76)	45.1	19.5	44/56	45.1	G
Scapula	51	51 (35-74)	39.2	15.7	45/55	41.2	A
Ankle	631	50 (31-64)	33.0	5.9	46/54	62.4	A
Distal ulna	34	44 (24-76)	38.2	23.5	61/39	38.2	A
Metatarsus	429	44 (26-60)	25.9	4.2	37/63	65.4	A
Proximal radius	263	43 (28-56)	21.3	3.8	47/53	55.1	D
Midfoot	37	40 (28-58)	21.6	2.7	44/56	40.5	C
Distal tibia	55	40 (27-52.5)	17.0	3.8	65/35	30.9	D
Fibula	29	39 (26-48)	10.3	3.4	72/28	17.2	B
Clavicle	280	36.5 (23-59)	24.3	9.6	71/29	33.6	G
Calcaneus	55	36.5 (23-51.5)	18.2	1.8	77/23	16.4	B
Finger	677	36 (23-50)	16.1	4.7	65/35	20.3	B
Toe	123	33 (22.5-48)	12.2	1.6	55/45	11.4	C
Talus	33	33 (23-44.5)	15.2	0.0	61/39	30.3	C
Tibial diaphysis	78	31 (22-50.5)	14.3	7.6	79/21	23.8	A
Carpus	205	28 (22-46)	13.2	1.5	70/30	40.5	B
Forearm diaphysis	68	25.5 (19-54)	20.6	7.4	78/22	23.5	H
Metacarpus	737	25 (20-38)	9.0	2.2	79/21	17.8	B
Sesamoid	1	21	-	-	100/0	-	-

Table 5.7 The number and patient age- and gender-related details for all fracture types occurring in Edinburgh adults, and presented in this thesis. The fracture types are arranged in order of decreasing patient age distribution. The proportions of older (60 yrs +) and elderly (80 yrs +) patients affected are given, as well as the proportion of injuries resulting from a low energy simple fall. Curve type relates to the pattern of fracture distribution, as described by Court-Brown and Caesar⁸⁸. The pink shaded cells represent the 10 highest values within each column.

The data in Table 5.7 show that proximal femoral, femoral diaphyseal, distal femoral, and proximal and distal humeral fractures are fragility fractures, in that they display all five of these important characteristics. Fractures of the pelvis, patella, distal radius and proximal ulna display four important characteristics and should also be considered fragility fractures. Notably, three characteristics are present in fractures of the humeral diaphysis and proximal forearm.

A closer examination of the fragility fracture pattern details outlined in Section 3 reveals that certain subtypes display more convincing fragility characteristics than others. For example, even though the numbers in the present series were small, femoral head fractures occurred in a much younger patient group and resulted from high energy trauma. Femoral head fractures can not be considered fragility fractures. Femoral diaphyseal fractures in men likewise occurred secondary to high energy injury, while subtrochanteric and periprosthetic fractures were associated with skeletal fragility. Distal femoral fracture patients also represented a diverse group, with partial articular (AO type B) fractures seen in younger adults and extra-articular or complete articular injuries involving an older group. Therefore, AO type A and C distal femoral fractures can be considered fragility fractures.

Proximal humerus fractures overall affected a typically fragile patient population. The large numbers identified convincingly illustrate the exponential rise in incidence associated with advancing age that Kanis defined as indicative of fragility injury⁴¹². However, closer analysis of AO fracture groups revealed that A1 (isolated greater tuberosity) and B3 (3-part fracture dislocations) injuries occurred in a younger adult cohort, and should not be considered as fragility fractures. In the distal humerus, it was the extra-articular trans-metaphyseal fractures that exhibited the most convincing association with fragility.

In the Edinburgh population the majority of pelvic ring fractures were undisplaced lateral compression injuries sustained by elderly women involved in low energy trauma. Elemental acetabular fractures were also suffered by an older adult group. Whilst it may be said that pelvic fractures in Lothian tend to represent fragility injuries, there remains a subset of younger pelvic fracture patients who suffer serious injury from high energy trauma. There is no doubt that low velocity fractures of the pubic ramus are typically osteoporotic injuries.

The large number of distal radius fractures encountered allowed for a detailed analysis of the many and varied fracture subtypes described in the AO classification system. In keeping with distal femoral injuries, type B fracture patterns were found in a younger patient group than types A and C, and should therefore not necessarily be considered as fragility injuries. Unsurprisingly, those injuries with metaphyseal comminution (particularly groups A3 and C2) more often occurred in the elderly and should be thought of as fragility fractures. The unexpected finding related to the C3.2 fractures. Often thought of as representing the severe articular fracture type, a significant number of these injuries occurred in older patients after seemingly low energy falls.

From the analyses of many previously published fracture series in Edinburgh adults, it can be seen that the age distribution of most commonly encountered fracture types is shifting to the right. Contributing factors include a continued trend towards stricter traffic and motoring legislation, an emphasis in recent decades on the importance of health and safety initiatives in the workplace, the gradual reduction in the amount and type of heavy industry in Scotland, and the expansion of the proportion of older adult groups within the Scottish and UK populations. The net effect on fracture patterns in Edinburgh includes the emergence of fragility characteristics within fracture types not typically or traditionally associated with osteoporosis. For example, olecranon fractures affected an older patient group than any other fracture type around the elbow region. A large number of bimalleolar and trimalleolar ankle fractures might now be considered fragility fractures. Finally, despite the relatively small numbers encountered, it was noted that pure depression tibial plateau fractures and multiple hand fractures in women occurred in older patients.

Cooper and colleagues (on behalf of the Working Group on Fracture Epidemiology), in their review of trends in osteoporotic fracture incidence, commented on the relative lack of data available from 1990 onwards⁴¹¹. They concluded that fragility fracture data need to be collected prospectively and evaluated rigorously, in order to detect trends that will impact on the future health burden of osteoporosis and its related fractures. The orthopaedic trauma unit of the Royal Infirmary of Edinburgh serves a defined adult patient population, and is well positioned to contribute substantially to future regional fragility fracture research.

5.4 Social deprivation and fractures in adults

The socioeconomic status of patients is an important factor in many areas of medicine and there is evidence that increasing social deprivation correlates with increased fracture incidence in children and young male adults^{83, 102-104}. Despite the frequency with which adult fractures occur, there has been little written about the role of deprivation in this patient group.

A number of researchers, analysing the effects of socioeconomic deprivation on the Scottish population, have used the Carstairs Score⁴¹³ as a deprivation measure^{83, 100, 107}. More recently, the Office for the Chief Statistician (Scotland) has recommended that researchers use the Scottish Index of Multiple Deprivation (SIMD). Consequently, use of the SIMD has become more frequent in the orthopaedic^{101, 108}, ophthalmological^{414, 415} and neurosurgical^{97, 416} literature.

Logistic regression analysis was used to control for the influence of a number of variables known to have an effect on fracture patterns, such as patient age and gender, the injury mode involved and fracture type. Fractures of the carpus, metacarpus, clavicle and tibial diaphysis are much more common in men than women. Fractures of the proximal femur, femoral diaphysis, proximal humerus and distal radius occur more frequently with advancing age. Court-Brown *et al* recently described the association between simple fall fractures and social deprivation across all adult age groups¹¹⁰. MacKenzie and colleagues have described deprivation in relation to high energy lower limb trauma⁹⁹. Associations have already been described between deprivation and fractures of the tibia¹⁰⁷ and hand^{108, 109}.

After controlling for confounding variables, the effect of increasing deprivation remained statistically significant. Figure 4.1 has shown a stronger correlation in men than in women. The overall clinical significance in men was also more striking. The fracture incidence seen in the most affluent decile was only 50% of that seen in the most deprived group. The strong overall correlation in men was mainly due to influence of metacarpal, distal radial, proximal humeral and ankle fractures. The overall effect of increasing deprivation on fracture incidence in women was less marked. It is clear that a stronger correlation exists for certain fracture types (Fig. 4.2), but the effect of deprivation on proximal femoral fractures was not as clear. It is interesting to note from Table 4.2 that the median age of hip fracture patients was 83 years. Court-Brown has suggested that the incidence and frequency of hip fractures

actually decreases with advancing deprivation, predominantly due to the fact that life expectancy in more deprived areas is markedly lower than the age at which hip fracture becomes increasingly common¹¹⁰.

In addition to fractures caused by a simple fall from a standing height, fractures resulting from other injury modes were also more commonly encountered in more deprived patients. This effect of deprivation was most marked in deciles 1 and 2. Analyses restricted to deciles 3 to 8 showed that in men all injury modes still showed correlation, suggesting a broad effect of socioeconomic disadvantage. In women, only fractures where the cause was unknown remained significantly affected by deprivation.

Calculation of the SDFRs presented in Table 4.6 illustrates the clinical consequence of socioeconomic deprivation. In men, the incidence of certain common fracture types can be almost *three times* as high in deprived areas than in areas of relative affluence. The difference is less pronounced in women, but a similar relationship exists. The results presented in this section are likely to apply to many communities, although Edinburgh is a relatively affluent city compared to other cities in the United Kingdom. The difference in fracture incidence between the most deprived and the most affluent may indeed be even greater in other areas. It seems clear, that in order to effectively plan trauma and orthopaedic services for different regions, it is important to understand the effects of social deprivation on the pattern of adult fractures.

5.5 Strengths, weaknesses, and future work

This thesis represents a considerable body of work and a detailed analysis of the large number of acute fractures occurring in the adult Edinburgh population over a 12 month period. The design and implementation of this investigation have significant strengths, but of course the results presented in Sections 2, 3 and 4 must also be interpreted within the context of some considerable limitations. Many of the weaknesses discussed here are typical of any large epidemiological study.

Numerator considerations

The way in which trauma and orthopaedic services are organised in the Scotland, and in Edinburgh in particular, lends significant advantage to the design and implementation of epidemiological fracture research. Firstly, the Scottish population is served by one National Health Service, and this is in stark contrast to many other countries, in particular those in North America, where healthcare is provided by multiple health services. Admittedly, Edinburgh does have a number of private health care providers and facilities, but none of these is set up to receive trauma. The Orthopaedic Trauma Unit at the Royal Infirmary of Edinburgh is the only trauma unit serving the regional adult population. An established trauma database exists, with numerator fracture data collected in a prospective fashion.

An important strength of this investigation was the quality of the data obtained. All fracture data were gathered by a dedicated orthopaedic registrar (SORT-IT trauma research fellow) for the duration of the study, thereby minimising the variability in coding. In addition, the recording and classification of fractures requiring inpatient treatment was performed on a daily basis during the Consultant-led trauma meetings, where any dubiety regarding the correct fracture classification could be dealt with by senior clinicians. In many other studies, fracture data are obtained from non-orthopaedic sources and the coding of injuries is performed by junior members of emergency department staff or non-medical administrative staff. An important concession, however, was the 'learning curve' involved with analysing thousands of plain radiographs and classifying fractures according to the AO system. Future work should include a small pilot study, or bedding in period, to allow the investigator to become familiar and fully conversant with the intricacies of his or her chosen system of classifying fractures. In the present study, cases that proved difficult to accurately classify were annotated and revisited at a later date.

Of course it is important to note that the trauma and orthopaedic services are not the first point of contact for patients who have suffered skeletal injury. The vast majority of patients present first to the emergency department or minor injuries unit, with a much smaller proportion referred to the trauma services by the general practitioner. The source of referral for fracture cases was not recorded during this study, but might prove an interesting addition to future work. The accurate ascertainment of fractures in this investigation was therefore heavily dependent on the emergency department clinicians identifying fracture cases and referring them onwards to the orthopaedic services. The Orthopaedic Trauma Unit fracture database was set up in 1988 and for many years clinicians in the emergency department have been encouraged to refer *all* fracture cases to the orthopaedic services. However, it is likely that a number of 'minor' fractures will have been treated definitively in the ED without onward referral. This represents a shortcoming of this study, and a potential strength of other investigations that use ED fracture data.

The diagnosis and classification of skeletal fracture relied upon the ability of the investigator to accurately interpret fracture lines on plain radiographs, and the learning curve associated with this has previously been alluded to. A significant strength of this research was high capture rate of radiographs, with a very small number of films being unobtainable for analysis (36 of 6,846 films, 0.5%). The introduction of the digital Picture Archive and Communication System (PACS) at the Royal Infirmary from November 2007 onwards was instrumental in the successful collection of required imaging. The most appropriate way of categorising fractures in epidemiological fracture research is to group these injuries according to how they are described anatomically and treated clinically, and this was done as part of this study. In addition, the AO system was used to comprehensively classify each fracture. A number of researchers have found only fair to poor intraobserver reliability with use of the AO system¹⁸⁻²³, especially with greater degrees of detail such as fracture grouping (A1, A2, A3 *etc.*) and subtyping (A1.1, A1.2, A1.3 *etc.*), and this is certainly a limitation of the results presented in this thesis.

Perhaps the greatest shortcoming of this investigation was the inability to truly capture all cases of skeletal fractures occurring in Edinburgh adults. The reasons for this were partly logistic and partly diagnostic. Maxillofacial fractures and fractures of the skull and cervical spine are not routinely treated by orthopaedic surgeons. The treatment of thoracolumbar fractures in Edinburgh is shared between the orthopaedic and neurosurgical services. The maxillofacial and neurosurgical services are at present situated in separate institutions from

the Royal Infirmary. It was simply not feasible to gather data from three hospitals during the same period of study, and therefore these injuries were excluded from analysis. In addition, the diagnosis of rib fractures and fragility fractures of the thoracolumbar spine are largely based upon clinical suspicion alone. Indeed, many patients suffering these injuries and others may not seek medical advice. The decision was therefore made to exclude these fractures from analysis.

Denominator considerations

The populations of Midlothian, East Lothian and the City of Edinburgh council areas form the catchment population for the Orthopaedic Trauma Unit. Demographical details for these populations were provided by the General Register Office for Scotland, and represented mid-year estimates for the year 2007. The calculation of these estimates from 2001 census data is the most accurate measure of the total number of individuals at risk of sustaining a fracture during the study period. There is now way of knowing how accurate the population estimates are, but it is likely that they become less accurate each year, until the next census is undertaken.

The total number of fractures presented in Section 3 of this thesis does not accurately reflect the fracture workload dealt with in the Orthopaedic Trauma Unit, as patients from West Lothian also receive inpatient orthopaedic treatment there. However, outpatient fracture cases are seen and treated at a separate institution in Livingston. For this reason, all patients residing in West Lothian were excluded from analysis. It is difficult to estimate just how many Edinburgh patients living in the catchment area of the Royal Infirmary chose to travel to neighbouring institutions for their fracture care. Future epidemiological work would benefit from obtaining simple patient data from neighbouring hospitals in order to ensure that the number of missed cases is minimised.

The age cut-off chosen to exclude paediatric cases was a considerable strength of this study. Local policy dictates that all patients aged 13 years or older should be treated at the Royal Infirmary, but personal communication with the paediatric orthopaedic clinicians at the Royal Hospital for Sick Children in Edinburgh revealed that they occasionally see and treat patients aged 13 years, and sometimes those aged 14 years. It therefore seemed appropriate to decide upon the age of 15 years or more as a suitable inclusion criterion for this investigation. Ideally, the inclusion of paediatric fractures in the present study would have

negated the requirement to exclude patients based upon age, but regrettably this was simply not logistically feasible.

Finally, the analysis of fractures in relation to patient socioeconomic deprivation presented in Section 4 is a strong addition to this thesis, as relatively little has been written on the topic. The analysis is underpinned by use of the Scottish Index of Multiple Deprivation (SIMD), an index which combines data from 38 indicators of deprivation across seven broad categories. The SIMD is likely to be a relatively blunt research tool, as deprivation is known to be multifactorial, but it is the measure currently recommended by Scottish government statisticians for use in epidemiological research.

Causation

The sets of circumstances surrounding the occurrence of an acute episode of skeletal fracture were termed the modes of injury. One of the great strengths of this study was the opportunity to obtain and record details relating to the circumstances surrounding the accident. These details were obtained directly from the injured subjects in almost all instances of fracture where patients required admission to hospital. For patients who were seen and treated on an outpatient basis, the mode of injury details were obtained from emergency department records, cross-referenced with the clinical orthopaedic notes. Other epidemiological studies, especially those obtaining data from the UK GPRD⁹⁴, have been unable to include information regarding the modes of injury because this data simply does not exist on the GPRD.

There are obviously a large number of categories that could have been used to describe the modes of injury. Early fracture epidemiology reports used very broad categories such as Falls at home, Other falls, Traffic accidents and Industrial accidents⁸⁵. Later studies used activity-related categories including Sport, Work, Household work, Education and Spare time⁹⁰. For this project, a large number of injury mode categories were used to determine the cause of fractures. The precise definitions of each injury mode, in particular falls from a height and falls down stairs, were carefully considered to ensure that any ambiguity was kept to a minimum. For the purposes of analysis and presentation, a number of the initial categories had to be combined, *e.g.* direct blows, punching injuries, missile injuries, and crush injuries. Causes of fracture that could not be sensibly placed in any specific category, were classified as 'other'.

Despite careful attention to detail in defining individual causation categories, one weakness of this study was the inevitable crossover between certain injury modes. A fall down two stairs was considered a *simple fall*, whereas a fall down three stairs was considered as a *fall down stairs*, when it is quite obvious that there is probably very little difference between these two sets of circumstances. Similarly, a *simple fall* only became a *fall from height* when it was considered that the patient had fallen from a distance of six feet or more, when it is clear that falling over from standing and falling from a height of five feet involve quite different amounts of energy transfer. In any event, the cut-off criteria of two stairs and six feet were decided in advance of the data collection period and were stringently adhered to throughout. Finally, it was clear that some injury circumstances could easily be considered to fall into more than one category. The best examples involved sports-related accidents. Should the tibial fracture suffered by the cyclist colliding with a fellow cyclist be considered a *Sports cycling* fracture or a *RTA* fracture? Has the BMX biker sustaining a clavicle fracture from a six foot jump suffered a *Sports BMX* fracture or a *fall from height* fracture? The goalkeeper sustaining a broken finger when kicked by an opponent might have suffered a *Sports football* injury or a *direct blow* fracture. It is impossible to overcome all the inherent difficulties involved with injury causation, and the best attempt was made during this study to use sensible definitions, to document them clearly, and to stick to them.

Multiplicity

With regards to multiple and recurrent fracture episodes, the criteria set out in Section 3.1 of this thesis were decided upon prior to commencing data collection. Patients were considered to have suffered multiple fractures if they presented with one or more of the fracture types outlined in Table 3.1. However, multiple ‘minor’ fractures such as those affecting the fingers or the toes were still considered to represent a ‘1 fracture’ episode. Segmental fractures of the long bones, bi- or tri-malleolar ankle fractures, and highly comminuted fractures where multiple distinct fracture lines were present, were also considered to represent a ‘1 fracture’ episode. Injuries involving two or more fractures of the metacarpal, carpal, metatarsal, tarsal, midfoot or hindfoot bones were considered as a ‘2 fracture’ episode, even if three or more bones were involved in some way as part of the same injury to that anatomical region. These decisions could be criticised as being imprecise, but a close analysis of the existing fracture epidemiology literature shed very little light on exactly how these events are routinely dealt with by researchers. Accordingly, the criteria were chosen based upon discussion with and guidance from Professor C.M. Court-Brown, who supervised this project.

The most significant weakness in terms of the way multiple fractures were described and presented was the obvious omission of certain fracture types that were excluded from this investigation. Clearly, a number of patients sustained associated fractures of the skull, ribs, facial bones or spinal column. Owing to the exclusion criteria adopted it would have been incorrect to include these injuries as part of multiple fracture episodes, while at the same time keep them excluded from analysis if they happened to occur in isolation. Finally, it must be stressed that the 'multiply injured' or polytrauma patient by definition has potentially suffered injury to multiple organ systems in addition to the skeleton. This study was not designed to explore the range and severity of trauma in the Edinburgh population, and the analysis of patients with multiple fractures can not be considered a surrogate for the analysis of polytrauma patients. Future epidemiological fracture work in Edinburgh would benefit from the inclusion of some form of trauma scoring system, such as the Injury Severity Score, in order to gain a more accurate insight into the proportion of fracture patients who present with polytrauma.

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LIST OF PUBLICATIONS RELATED TO THIS THESIS

Aitken SA, Rodrigues MA, Duckworth AD, Clement ND, McQueen MM, Court-Brown CM. Determining the incidence of adult fractures: how accurate are emergency department data? *Epidem Research Int* 2012; Article ID 837928, 7 pages, 2012.

Various research methods have been used to obtain skeletal fracture data and report the incidence of fractures. A large number of British studies have used data collected in Emergency Departments, and not data derived from Orthopaedic units. We hypothesised that fracture data will differ depending upon the methodology employed to capture it. Two commonly used sources of fracture data at our institution were compared, (the Emergency Department [ED] database and the Orthopaedic Trauma Unit [OTU] database), using a cohort of adult patients from our defined population as the study sample. We performed univariate analyses to identify differences between groups with accurate and inaccurate ED fracture diagnoses. We then performed a binary logistic regression analysis to determine the best predictors of diagnostic accuracy.

In one year, 7,449 patients were referred to the OTU. Three-quarters were referred with fractures. The overall false positive fracture referral rate was 25%. Several fracture subtypes were commonly over-diagnosed in the ED (carpal, proximal tibial, proximal radial, calcaneal, talar, and midfoot fractures). Regression analysis showed that patient age, patient gender, and the seniority of the referring clinician were independently predictive of an accurate fracture diagnosis.

We suggest that studies making use of ED fracture data may potentially overestimate the incidence of adult fractures.

Robertson GA, Wood AM, **Aitken SA**, Court-Brown CM. The epidemiology, morbidity and outcome of soccer-related fractures in a standard population. *Am J Sports Med* 2012; 40(8):1851-7.

Background: Soccer is the most common cause of sporting fracture, yet little is known about patient outcome following such fractures.

Purpose: To describe the epidemiology of soccer-related fractures, their morbidity and the likelihood of return to soccer post-injury in a known UK population at all skill levels.

Methods: All soccer fractures during 2007-2008 in the Edinburgh population were prospectively collected, with the diagnosis confirmed by the senior author when patients attended the only adult orthopaedic service in Lothian. Patients living outside the region were excluded from the study. Patients were contacted in August 2010 to ascertain their progress in return to soccer.

Results: 367 fractures were recorded over the study period in 357 patients. 312 fractures (85%) in 303 patients (85%) were followed up with a mean interval of 30 months (range 24-36 months). The mean time for return to soccer from injury was 15 weeks (range 0-104 weeks; SD 17 weeks). For patients with lower limb injuries, the mean time was 26 weeks (range 4-104 weeks; SD 22 weeks) compared to 9 weeks for patients with upper limb

injuries (range 0-64 weeks; SD 8 weeks). 14% of the whole cohort did not return to soccer. 83% returned to soccer at the same level or higher. 39% had ongoing related problems, yet only 8% had impaired soccer ability because of these problems. Fractures with the highest morbidity in not returning to soccer were: Clavicle 24%; Distal Radius 21%; Tibial Diaphysis 20%.

Conclusions: Most patients sustaining a fracture playing soccer *will* return to soccer at a similar level. While over one third of them will have persisting symptoms 2 years post-injury, for the majority this will not impair their soccer ability.

Burns MJ, **Aitken SA**, McRae D, Duckworth AD, Gray A. The impact of suspected scaphoid injury. *Scot Med J* 2012; (*in press*).

Introduction: Undiagnosed and untreated scaphoid fractures have poorer outcomes and many patients are unnecessarily immobilised for prolonged periods of time to avoid missing occult injuries. Magnetic Resonance Imaging (MRI) has high sensitivity and specificity in detecting occult scaphoid fractures, but many units do not routinely use this imaging modality in the diagnostic pathway. We aimed to determine the patterns of suspected scaphoid injuries, report the process of care, and calculate the costs involved in their management.

Methods: We prospectively identified all adult patients referred to fracture clinic at the Royal Infirmary of Edinburgh with a scaphoid-related injury, between October 2007 and September 2008. Clinical notes were examined retrospectively. We defined three injury groups: true fractures, occult fractures, and suspected scaphoid injuries. We analysed patient demographics, treatment timelines, and the treatment costs involved.

Results: Fracture clinic received 537 scaphoid related referrals. There were 87 true fractures, 43 occult fractures and 407 suspected injuries, incurring average treatment costs of £1,173, £773, and £384 respectively. Occult fractures accounted for 33% of all confirmed scaphoid fractures. The majority of scaphoid-related referrals (76%) were never proven to have a scaphoid fracture, and many were unnecessarily immobilised. The costs involved in the treatment of suspected scaphoid injuries were found to be higher than the cost of MRI (£97).

Conclusion: In this group of suspected scaphoid injury we believe the introduction of an early MRI protocol would lead to an earlier definitive diagnosis and potentially a more cost effective service.

Duckworth AD, Jenkins PJ, **Aitken SA**, Clement ND, Court-Brown CM, McQueen MM. Scaphoid fracture epidemiology. *J Trauma* 2012; 72(2):E41-5.

Background: The current available literature related to scaphoid fracture epidemiology is inconsistent. The aim of this study was to describe the epidemiology of true scaphoid fractures in a defined adult population.

Methods: Using a prospective database, we identified all patients who sustained a radiographically confirmed acute fracture of the scaphoid over a 1-year period. Age, gender, mechanism of injury, the Herbert fracture classification, and associated injuries were recorded and analyzed.

Results: There were 151 scaphoid fractures diagnosed giving an annual incidence of 29 per 100,000 (95% confidence interval, 25–34). The median age of males was significantly younger when compared with females ($p = 0.002$), with a male ($n = 105$) predominance seen ($p = 0.001$). Low-energy falls from a standing height were most common (40.4%), but with males being significantly more likely to sustain their fracture after a high-energy injury ($p = 0.001$). The most common fracture was Herbert classification B2 ($n = 55$, 36.4%), with unstable fractures more common in younger patients ($p = 0.025$) following a high-energy injury ($p = 0.042$).

Conclusions: We have reported the epidemiology of true scaphoid fractures, with young males at risk of sustaining a fracture. Knowledge of the true incidence of scaphoid fractures and an understanding of the demographic risk factors are essential when assessing the suspected scaphoid fracture, particularly when considering further imaging modalities.

Clement ND, **Aitken SA**, Duckworth AD, McQueen MM, Court-Brown CM. Multiple fractures in the elderly. *J Bone Joint Surg Br* 2012; 94(2):231-6.

We present the prevalence of multiple fractures in the elderly in a single catchment population of 780,000 treated over a 12-month period and describe the mechanisms of injury, common patterns of occurrence, management, and the associated mortality rate. A total of 2335 patients, aged ≥ 65 years of age, were prospectively assessed and of these 119 patients (5.1%) presented with multiple fractures. Distal radial (odds ratio (OR) 5.1, $p < 0.0001$), proximal humeral (OR 2.2, $p < 0.0001$) and pelvic (OR 4.9, $p < 0.0001$) fractures were associated with an increased risk of sustaining associated fractures. Only 4.5% of patients sustained multiple fractures after a simple fall, but due to the frequency of falls in the elderly this mechanism resulted in 80.7% of all multiple fractures. Most patients required admission ($> 80\%$), of whom 42% did not need an operation but more than half needed an increased level of care before discharge (54%). The standardised mortality rate at one year was significantly greater after sustaining multiple fractures that included fractures of the pelvis, proximal humerus or proximal femur ($p < 0.001$). This mortality risk increased further if patients were < 80 years of age, indicating that the existence of multiple fractures after low-energy trauma is a marker of mortality.

Duckworth AD, Clement ND, **Aitken SA**, Court-Brown CM, McQueen MM. The epidemiology of fractures of the proximal ulna. *Injury* 2012; 43(3):343-6.

Introduction: The aim of our study was to report the epidemiological characteristics of fractures of the proximal ulna.

Methods: From our prospective trauma database of 6872 fractures, we identified all acute fractures of the proximal ulna from a 1-year period between July 2007 and June 2008. Age, gender, mode of injury, fracture classifications, associated injuries and treatment were the factors documented and analysed.

Results: There were 78 fractures of the proximal ulna with a mean age of 57 years (15-97). Males ($n=35$) sustained their fracture at a significantly younger age than females ($p=0.041$), with no gender predominance seen ($p=0.365$). The overall fracture distribution was a

unimodal older male and unimodal older female type-F curve. The most common mode of injury was a simple fall from standing height (n=52, 67%), with younger patients more likely to sustain their injuries following a high-energy mechanism such as sports or a motor vehicle collision (p<0.001). Seventeen (22%) patients sustained associated injuries to the ipsilateral limb, with an associated proximal radial fracture most frequent (n=13, 17%). Open fractures were seen in five (6.4%) patients. A total of 64 patients had a fracture of the olecranon, with the Mayo 2A most frequently seen (n=47, 60%).

Conclusions: Fractures of the proximal ulna are fragility fractures that predominantly occur in elderly patients. Given the number of elderly patients sustaining these injuries, research is needed to determine the role of non-operative treatment for these fractures, particularly in patients with multiple co-morbidities and low functional demands.

Duckworth AD, Clement ND, Jenkins PJ, **Aitken SA**, Court-Brown CM, McQueen MM. The epidemiology of radial head and neck fractures. *J Hand Surg Am* 2012; 37(1):112-9.

Purpose: The aim of this study was to define the epidemiological characteristics of proximal radial fractures.

Methods: Using a prospective trauma database of 6,872 patients, we identified all patients who sustained a fracture of the radial head or neck over a 1-year period. Age, sex, socioeconomic status, mechanism of injury, fracture classification, and associated injuries were recorded and analyzed.

Results: We identified 285 radial head (n = 199) and neck (n = 86) fractures, with a patient median age of 43 years (range, 13-94 y). The mean age of male patients was younger when compared to female patients for radial head and neck fractures, with no gender predominance seen. Gender did influence the mechanism of injury, with female patients commonly sustaining their fracture following a low-energy fall. Radial head fractures were associated more commonly with complex injuries according to the Mason classification, while associated injuries were related to age, the mechanism of injury, and increasing fracture complexity.

Conclusions: Radial head and neck fractures have distinct epidemiological characteristics, and consideration for osteoporosis in a subset of patients is recommended.

Clement ND, **Aitken SA**, Duckworth AD, McQueen MM, Court-Brown CM. The outcome of fractures in very elderly patients. *J Bone Joint Surg Br* 2011; 93(6):806-10.

We compared case-mix and outcome variables in 1310 patients who sustained an acute fracture at the age of 80 years or over. A group of 318 very elderly patients (≥ 90 years) was compared with a group of 992 elderly patients (80 to 89 years), all of whom presented to a single trauma unit between July 2007 and June 2008. The very elderly group represented only 0.6% of the overall population, but accounted for 4.1% of all fractures and 9.3% of all orthopaedic trauma admissions. Patients in this group were more likely to require hospital admission (odds ratio 1.4), less likely to return to independent living (odds ratio 3.1), and to have a significantly longer hospital stay (ten days, p = 0.01). The 30- and 120-day unadjusted mortality was greater in the very elderly group. The 120-day mortality associated

with non-hip fractures of the lower limb was equal to that of proximal femoral fractures, and was significantly increased with a delay to surgery > 48 hours for both age groups ($p = 0.04$). This suggests that the principle of early surgery and mobilisation of elderly patients with hip fractures should be extended to include all those in this vulnerable age group.

Anakwe RE, **Aitken SA**, Cowie JG, Middleton SD, Court-Brown CM. The epidemiology of fractures of the hand and the influence of social deprivation. *J Hand Surg Eur Vol* 2011; 36(1):62-5.

This study investigates the relationship between the epidemiology of hand fractures and social deprivation. Data were collected prospectively in a single trauma unit serving a well-defined population. The 1382 patients treated for 1569 fractures of the metacarpals or phalanges represented an incidence of hand fracture of 3.7 per 1000 per year for men and 1.3 per 1000 per year for women. Deprivation was not directly associated with the incidence of hand fracture. Common mechanisms of injury are gender specific. Fractures of the little finger metacarpal were common (27% of the total) and were associated with social deprivation in men ($P = 0.017$). For women, fractures where the mechanism of injury was unclear or the patient was intoxicated and could not recall the mechanism showed a clear association with deprivation. Affluent patients were more likely to receive operative treatment. Social deprivation influences both the pattern and management of hand fractures.

Court-Brown CM, **Aitken SA**, Ralston SH, McQueen MM. The relationship of fall-related fractures to social deprivation. *Osteoporosis Int* 2011; 22(4):1211-8.

Introduction: This study examines the relationship between social deprivation and fall-related fractures. Social deprivation has been shown to be a predisposing factor in a number of diseases. There is evidence that it is implicated in fractures in children and young adults, but the evidence that it is associated with fragility fractures in older adults is weak. As fragility fractures are becoming progressively more common and increasingly expensive to treat, the association between social deprivation and fractures is important to define.

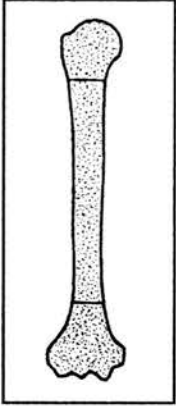
Methods: All out-patient and in-patient fractures presenting to the Royal Infirmary of Edinburgh over a 1-year period were prospectively recorded. The fractures caused by falls from a standing height were analysed in all patients of at least 15 years of age. The data were used to analyse the relationship between deprivation and fractures in all age groups.

Results: The incidence of fall-related fractures correlated with social deprivation in all age groups including fragility fractures in the elderly. The overall spectrum of fractures was not affected by social deprivation although the prevalence of proximal femoral fractures decreased with increasing deprivation. The average age of patients with fractures also decreased with increasing social deprivation as did the requirement for in-patient treatment.

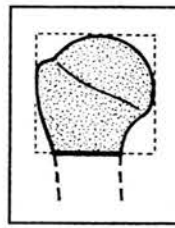
Conclusions: This is the first study to show the relationship between fall-related fractures and social deprivation in older patients. We believe that the decreased incidence of proximal femoral fractures, and the lower average age of patients with fall-related fractures, in the socially deprived relates to the relative life expectancies in the different deprivation deciles.

HUMERUS

BONE: HUMERUS (1)



Location: Proximal segment (11)

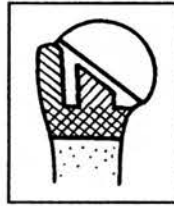


Types:

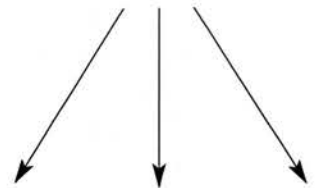
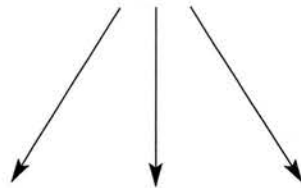
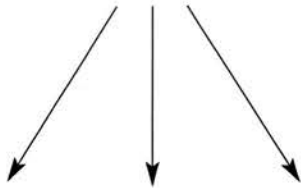
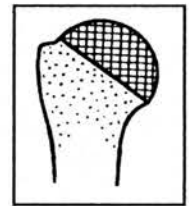
A. Extra-articular, unifocal fracture (11-A)



B. Extra-articular, bifocal fracture (11-B)



C. Articular fractures (11-C)



Groups:

Humerus proximal segment, extra-articular unifocal (11-A)

1. Avulsion of tuberosity (11-A1)

2. Impacted metaphysis (11-A2)

3. Non-impacted metaphysis fracture (11-A3)

Humerus, proximal segment, extra-articular bifocal (11-B)

1. With metaphyseal impaction (11-B1)

2. Without metaphyseal impaction (11-B2)

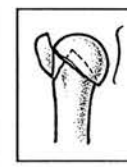
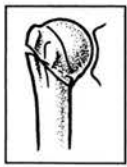
3. With glenohumeral dislocation (11-B3)

Humerus, proximal segment, articular fractures (11-C)

1. Articular fracture with slight displacement impacted valgus fracture (11-C1)

2. Articular fracture impacted with marked displacement (11-C2)

3. Articular fracture with glenohumeral dislocation (11-C3)



These fractures represent three part fractures, or fracture dislocations by the Neer classification.

Subgroups and Qualifications:

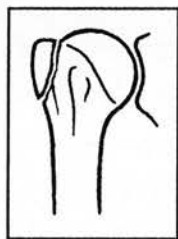
Humerus, proximal, extra-articular, unifocal tuberosity (11-A1)

- 1. Greater tuberosity not displaced (11-A1.1)
- 2. Greater tuberosity displaced (11-A1.2)
 - (1) superior,
 - (2) posterior

- 3. With glenohumeral dislocation (11-A1.3)

- (1) anterior and medial plus posterior cephalic notch
- (2) anterior and medial plus greater tuberosity
- (3) erecta and greater tuberosity
- (4) posterior and lesser tuberosity

A1



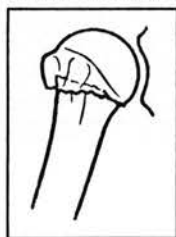
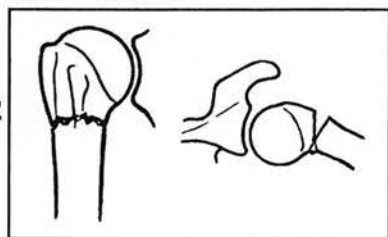
Humerus, proximal, extra-articular, unifocal, impacted metaphyseal (11-A2)

- 1. Without frontal malalignment (11-A2.1)
 - (1) without sagittal malalignment
 - (2) posterior impaction
 - (3) anterior impaction
- 2. With varus malalignment (11-A2.2)
 - (1) pure medial impaction
 - (2) posterior and medial impaction
 - (3) anterior and medial impaction

- 3. With valgus malalignment (11-A2.3)

- (1) pure lateral impaction
- (2) posterior and lateral impaction
- (3) anterior and lateral impaction

A2



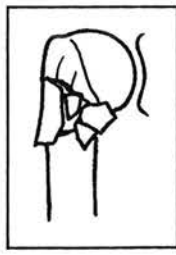
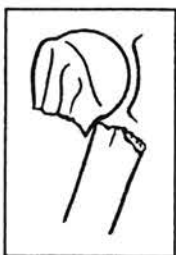
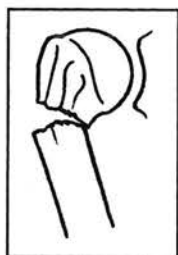
Humerus, proximal, extra-articular, unifocal, non-impacted metaphyseal (11-A3)

- 1. Simple with angulation (11-A3.1)
- 2. Simple with translation (11-A3.2)
 - (1) lateral
 - (2) medial
 - (3) with glenohumeral dislocation

- 3. Multifragmentary (11-A3.3)

- (1) wedge
- (2) complex
- (3) glenohumeral dislocation

A3



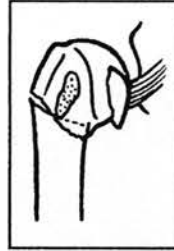
Humerus, proximal, extra-articular, bifocal, with metaphyseal impaction (11-B1)

- 1. Lateral plus greater tuberosity (11-B1.1)**
 (1) pure lateral impaction
 (2) posterior and lateral impaction
 (3) anterior and lateral impaction

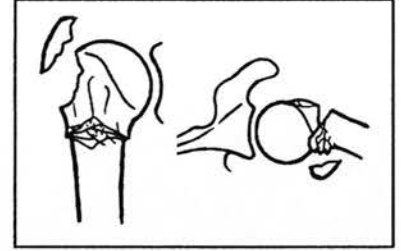


B1

- 2. Medial plus lesser tuberosity (11-B1.2)**
 (1) pure lateral impaction
 (2) posterior and lateral impaction
 (3) anterior and lateral impaction



- 3. Posterior plus greater tuberosity (11-B1.3)**



Humerus, proximal, extra-articular, bifocal, without metaphyseal impaction (11-B2)

- 1. Without rotatory displacement of the epiphyseal fracture fragment (11-B2.1)**



B2

- 2. With rotatory displacement of the epiphyseal fracture fragment (11-B2.2)**
 (1) greater tuberosity separated
 (2) lesser tuberosity separated



- 3. Multifragmentary metaphysis plus one of the tuberosities (11-B2.3)**
 (1) lesser tuberosity
 (2) greater tuberosity



Humerus, proximal, extra-articular, bifocal with glenohumeral dislocation (11-B3)

- 1. "Vertical" cervical line plus greater tuberosity intact plus anterior medial dislocation (11-B3.1)**



B3

- 2. "Vertical" cervical line plus greater tuberosity fracture plus anterior medial dislocation (11-B3.2)**



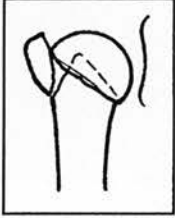
- 3. Lesser tuberosity fracture plus posterior dislocation (11-B3.3)**
 (1) without anterior cephalic notch
 (2) with anterior cephalic notch



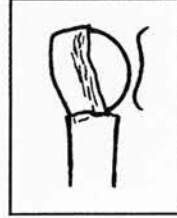
Humerus, proximal, articular fracture with slight displacement (11-C1)

1. Cephalotubercular with valgus malalignment (11-C1.1)

C1

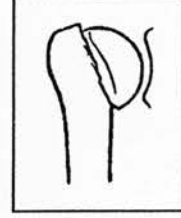


2. Cephalotubercular with varus malalignment (11-C1.2)



3. Anatomical neck (11-C1.3)

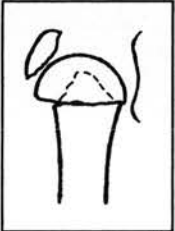
(1) nondisplaced
(2) displaced



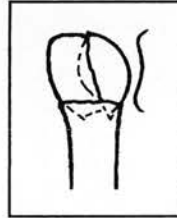
Humerus, proximal, articular fracture impacted with marked displacement (11-C2)

1. Cephalotubercular with valgus malalignment (11-C2.1)

C2



2. Cephalotubercular with varus malalignment (11-C2.2)



3. Transcephalic (double profile image on x-ray) and tubercular, with varus malalignment (11-C2.3)

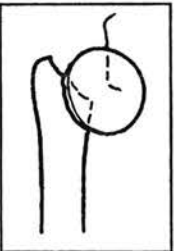


Humerus, proximal, articular fracture dislocated (11-C3)

1. Anatomical neck (11-C3.1)

(1) anterior
(2) posterior

C3



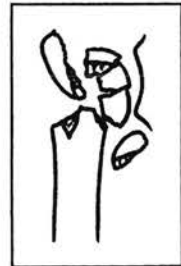
2. Anatomical neck and tuberosities (11-C3.2)

(1) head impacted
(2) head not impacted

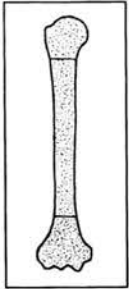


3. Cephalotubercular fragmentation (11-C3.3)

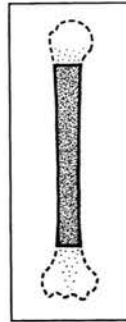
(1) head intact
(2) head fragmented



BONE: HUMERUS (1)



Location: Diaphyseal segment (12)



Types:

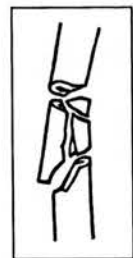
A. Simple fracture (12-A)



B. Wedge fracture (12-B)



C. Complex fracture (12-C)



Groups:

Humerus diaphyseal, simple (12-A)

1. Spiral (12-A1)

2. Oblique ($\geq 30^\circ$) (12-A2)

3. Transverse ($< 30^\circ$) (12-A3)

Humerus diaphyseal, wedge (12-B)

1. Spiral wedge (12-B1)

2. Bending wedge (12-B2)

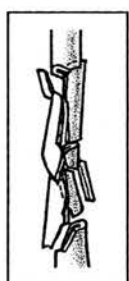
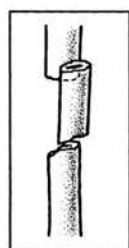
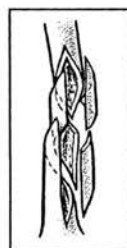
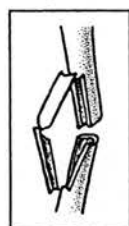
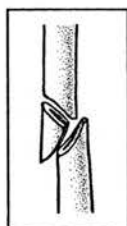
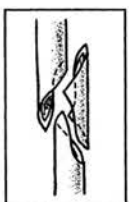
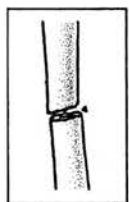
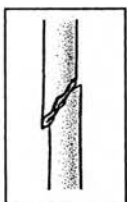
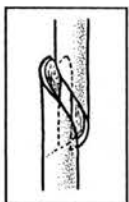
3. Fragmented wedge (12-B3)

Humerus diaphyseal, complex (12-C)

1. Spiral (12-C1)

2. Segmental (12-C2)

3. Irregular (12-C3)



Subgroups and Qualifications:

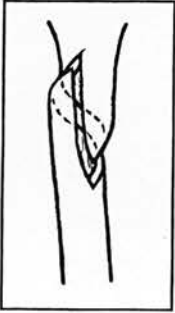
Humerus diaphyseal, simple, spiral (12-A1)

1. Proximal zone (12-A1.1)

2. Middle zone (12-A1.2)

3. Distal zone (12-A1.3)

A1



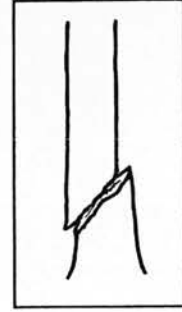
Humerus diaphyseal, simple, oblique ($\geq 30^\circ$) (12-A2)

1. Proximal zone (12-A2.1)

2. Middle zone (12-A2.2)

3. Distal zone (12-A2.3)

A2



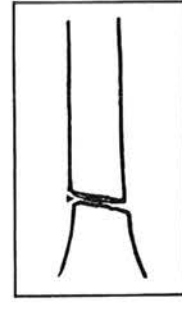
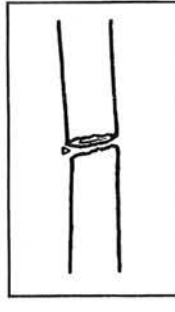
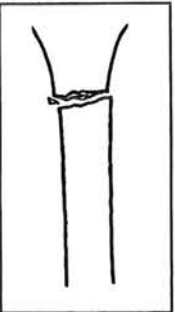
Humerus diaphyseal, simple, transverse ($< 30^\circ$) (12-A3)

1. Proximal zone (12-A3.1)

2. Middle zone (12-A3.2)

3. Distal zone (12-A3.3)

A3



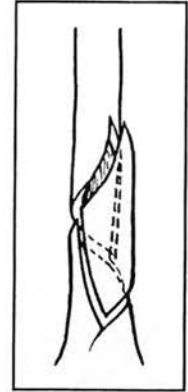
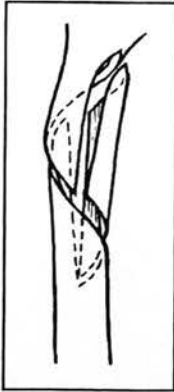
Humerus diaphyseal, wedge, spiral (12-B1)

1. Proximal zone (12-B1.1)

2. Middle zone (12-B1.2)

3. Distal zone (12-B1.3)

B1



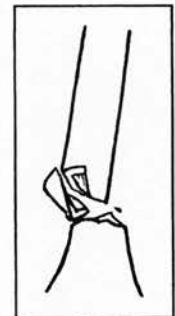
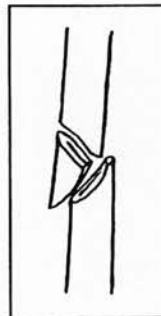
Humerus diaphyseal, wedge, bending (12-B2)

1. Proximal zone (12-B2.1)

2. Middle zone (12-B2.2)

3. Distal zone (12-B2.3)

B2



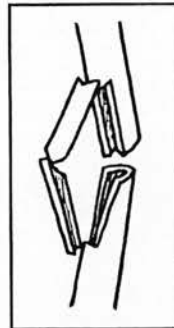
Humerus diaphyseal, wedge, fragmented (12-B3)

1. Proximal zone (12-B3.1)

2. Middle zone (12-B3.2)

3. Distal zone (12-B3.3)

B3



Humerus diaphyseal, complex, spiral (12-C1)

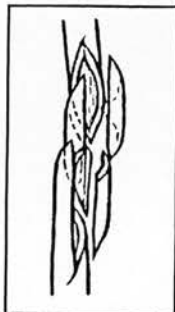
- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal

1. With 2 intermediate fragments (12-C1.1)



C1

2. With 3 intermediate fragments (12-C1.2)



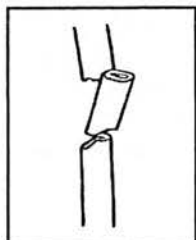
3. With more than 3 intermediate fragments (12-C1.3)



Humerus, diaphyseal, complex segmental (12-C2)

1. With 1 intermediate segmental fragment (12-C2.1)

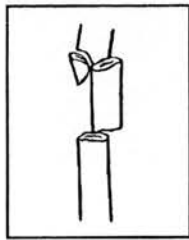
- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal
- (4) oblique lines
- (5) transverse and oblique lines



C2

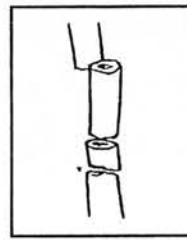
2. With 1 intermediate segmental and additional wedge fragments (12-C2.2)

- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal
- (4) distal wedge
- (5) 2 wedges, proximal and distal



3. With 2 intermediate segmental fragments (12-C2.3)

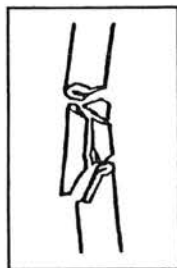
- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal



Humerus, diaphyseal, complex irregular (12-C3)

1. With 2 or 3 intermediate fragments (12-C3.1)

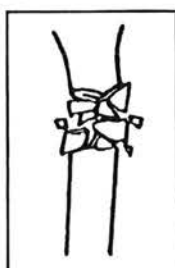
- (1) 2 main intermediate fragments
- (2) 3 main intermediate fragments



C3

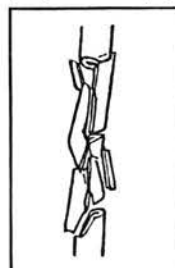
2. With limited shattering (<4cm) (12-C3.2)

- (1) proximal zone
- (2) middle zone
- (3) distal zone

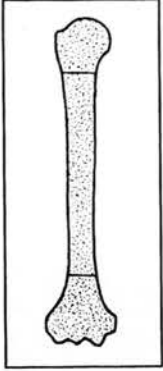


3. With extensive shattering (>4cm) (12-C3.3)

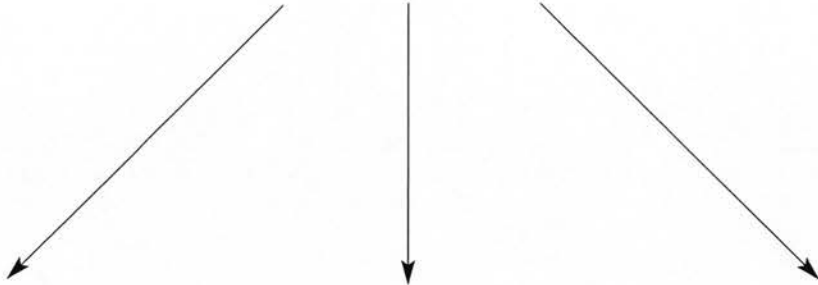
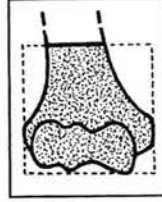
- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal



BONE: HUMERUS (1)

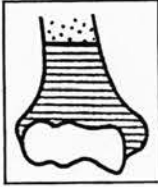


Location: Distal segment (13)



Types:

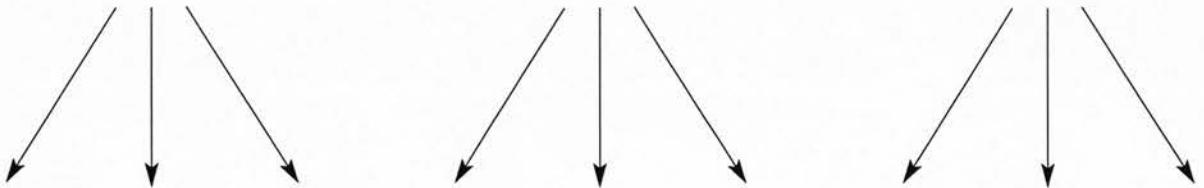
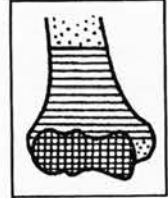
A. Extra-articular fracture (13-A)



B. Partial articular fracture (13-B)



C. Complete articular fracture (13-C)



Groups:

Humerus distal segment, extra-articular (13-A)

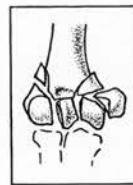
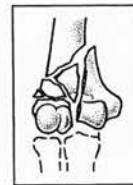
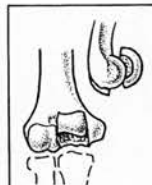
- 1. Apophyseal avulsion (13-A1)
- 2. Metaphyseal simple (13-A2)
- 3. Metaphyseal multifragmentary (13-A3)

Humerus distal segment, partial articular (13-B)

- 1. Lateral sagittal (13-B1)
- 2. Medial sagittal (13-B2)
- 3. Frontal (13-B3)

Humerus distal segment, complete articular (13-C)

- 1. Articular simple, metaphyseal simple (13-C1)
- 2. Articular simple, metaphyseal multifragmentary (13-C2)
- 3. Articular, metaphyseal multifragmentary (13-C3)



Subgroups and Qualifications:

Humerus, distal, extra-articular apophyseal avulsion (13-A1)

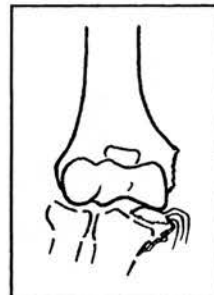
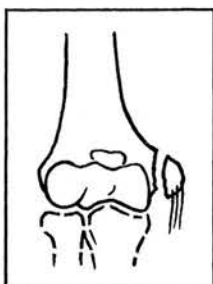
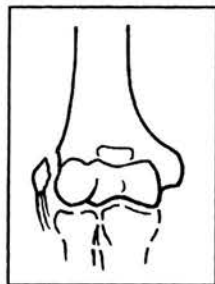
1. Lateral epicondyle (13-A1.1)

2. Medial epicondyle, non-incarcerated (13-A1.2)

3. Medial epicondyle, incarcerated (13-A1.3)

- (1) non-displaced
- (2) displaced
- (3) fragmented

A1



Humerus, distal, extra-articular metaphyseal simple (13-A2)

1. Oblique downwards and inwards (13-A2.1)

2. Oblique downwards and outwards (13-A2.2)

3. Transverse (13-A2.3)

(2) juxta-epiphyseal with posterior displacement (Kocher I)

(3) juxta-epiphyseal with anterior displacement (Kocher II)

A2



Humerus, distal, extra-articular metaphyseal multifragmentary (13-A3)

1. With intact wedge (13-A3.1)

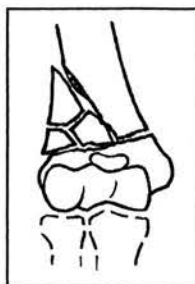
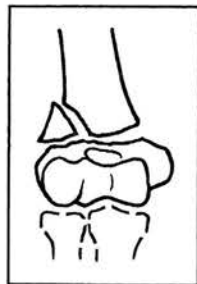
2. With fragmented wedge (13-A3.2)

3. Complex (13-A3.3)

- (1) lateral
- (2) medial

- (1) lateral
- (2) medial

A3



Humerus, distal, partial articular lateral sagittal (13-B1)

1. Capitellum (13-B1.1)

- (1) through the capitellum (Milch I)
- (2) between capitellum and trochlea

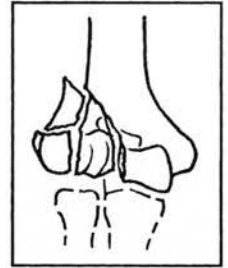
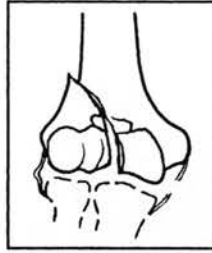
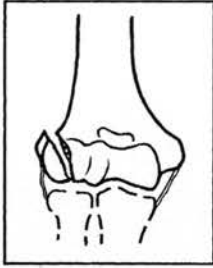
2. Transtrochlear simple (13-B1.2)

- (1) medial collateral ligament intact
- (2) medial collateral ligament ruptured
- (3) metaphyseal simple (classic Milch II) lateral condyle
- (4) metaphyseal wedge
- (5) metaphysio-diaphyseal

3. Transtrochlear multifragmentary (13-B1.3)

- (1) epiphysio-metaphyseal
- (2) epiphysio-metaphyseal-diaphyseal

B1



Humerus, distal, partial articular, medial sagittal (13-B2)

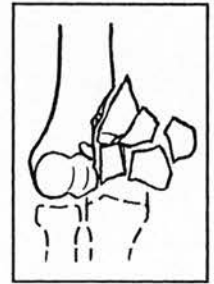
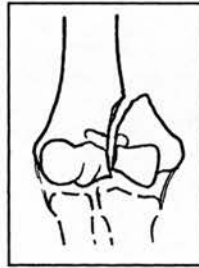
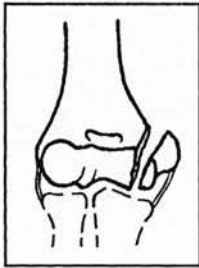
1. Transtrochlear simple, through medial side (Milch I) (13-B2.1)

2. Transtrochlear simple, through the groove (13-B2.2)

3. Transtrochlear multifragmentary (13-B2.3)

- (1) epiphysio-metaphyseal
- (2) epiphysio-metaphyseal-diaphyseal

B2



Humerus, distal, partial articular, frontal (13-B3)

1. Capitellum (13-B3.1)

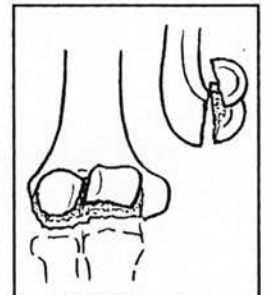
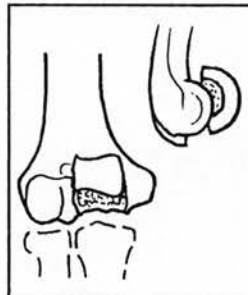
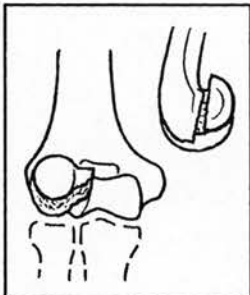
- (1) incomplete (Kocher-Lorenz)
- (2) complete (Hahn-Steinthal 1)
- (3) with trochlear component (Hahn-Steinthal 2)
- (4) fragmented

2. Trochlea (13-B3.2)

- (1) simple
- (2) fragmented

3. Capitellum and trochlea (13-B3.3)

B3

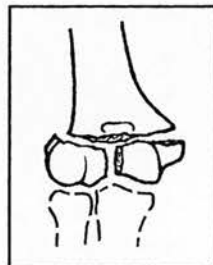
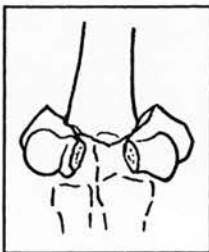
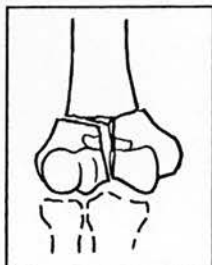


Humerus, distal complete, articular simple, metaphyseal simple (13-C1)

- 1. With slight displacement (13-C1.1)
 - (1) Y-shaped
 - (2) T-shaped
 - (3) V-shaped
- 2. With marked displacement (13-C1.2)
 - (1) Y-shaped
 - (2) T-shaped
 - (3) V-shaped

3. T-shaped epiphyseal (13-C1.3)

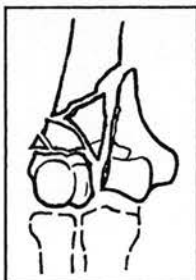
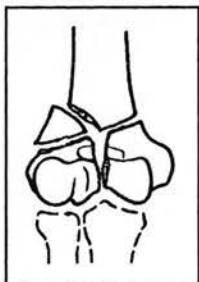
C1



Humerus, distal, complete articular simple metaphyseal multifragmentary (13-C2)

- 1. With intact wedge (13-C2.1)
 - (1) metaphyseal lateral
 - (2) metaphyseal medial
 - (3) metaphysio-diaphyseal-lateral
 - (4) metaphysio-diaphyseal-medial
- 2. With a fragmented wedge (13-C2.2)
 - (1) metaphyseal lateral
 - (2) metaphyseal medial
 - (3) metaphysio-diaphyseal-lateral
 - (4) metaphysio-diaphyseal-medial
- 3. Complex (13-C2.3)

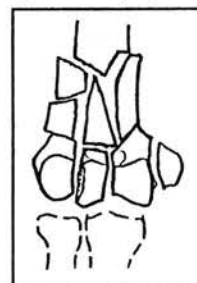
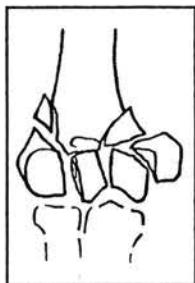
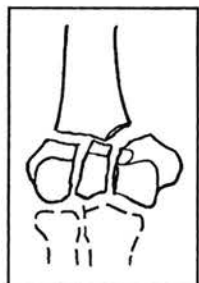
C2



Humerus, distal, complete multifragmentary (13-C3)

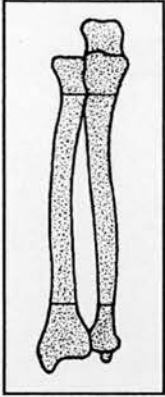
- 1. Metaphyseal simple (13-C3.1)
 - (1) intact
 - (2) fragmented
- 3. Metaphyseal complex (13-C3.3)
 - (1) localized
 - (2) extending into diaphysis

C3

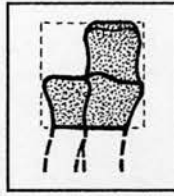


RADIUS/ULNA

BONE: RADIUS/ULNA (2)



Location: Proximal segment (21)



Types:

A. Extra-articular (21-A)



B. Articular fracture involving articular surface of only 1 of the 2 bones (21-B)



C. Articular fracture involving articular surface of 2 bones (21-C)



Groups:

Radius/ulna, proximal, extra-articular (21-A)

Radius/ulna, proximal, articular surface one bone (21-B)

Radius/ulna, proximal, articular both bones (21-C)

1. Ulna only (21-A1)

2. Radius only (21-A2)

3. Radius and ulna (21-A3)

1. Ulna fractured, 2. Radius fractured, radius intact (21-B1)

2. Ulna fractured, 2. Radius fractured, ulna intact (21-B2)

3. Articular of 1 bone, extra-articular of other (21-B3)

1. Simple of both bones (21-C1)

2. Simple of 1, multifragmentary of other (21-C2)

3. Multifragmentary of both (21-C3)

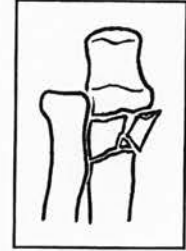
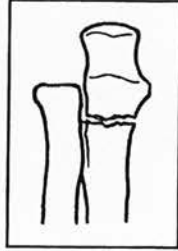


Subgroups and Qualifications:

Radius/ulna, proximal, extra-articular ulna fractured (21-A1)

- 1. Avulsion of triceps insertion from olecranon (21-A1.1)
- 2. Metaphyseal simple (21-A1.2)
- 3. Metaphyseal multifragmentary (21-A1.3)

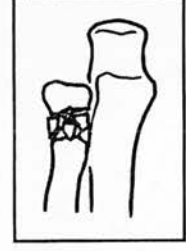
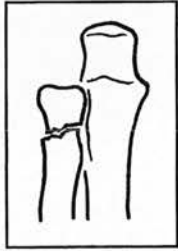
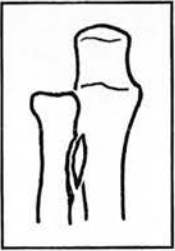
A1



Radius/ulna, proximal, extra-articular radius fractured (21-A2)

- 1. Avulsion of bicipital tuberosity of radius (21-A2.1)
- 2. Neck simple (21-A2.2)
- 3. Neck multifragmentary (21-A2.3)

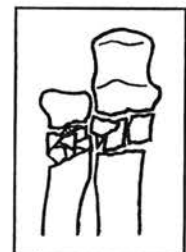
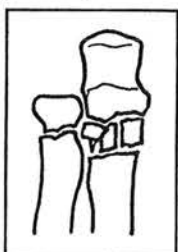
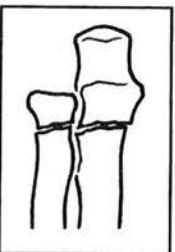
A2



Radius/ulna, proximal, extra-articular, fracture both bones (21-A3)

- 1. Simple of both bones (21-A3.1)
- 2. Multifragmentary of 1 bone and simple of other (21-A3.2)
(1) multifragmentary ulna
(2) multifragmentary radius
- 3. Multifragmentary of both bones (21-A3.3)

A3



Radius/ulna, proximal, articular fracture ulna (21-B1)

1. Unifocal (21-B1.1)

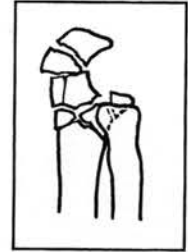
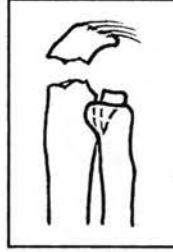
- (1) olecranon 1 line
- (2) olecranon 2 lines
- (3) olecranon multifragmentary
- (4) coronoid process alone

2. Bifocal (21-B1.2)

3. Bifocal multifragmentary (21-B1.3)

- (1) multifragmentary olecranon
- (2) multifragmentary coronoid process
- (3) multifragmentary of both

B1



Radius/ulna, proximal, articular, radial fracture (21-B2)

1. Simple (21-B2.1)

- (1) nondisplaced
- (2) displaced

2. Multifragmentary without depression (21-B2.2)

3. Multifragmentary with depression (21-B2.3)

B2



Radius/ulna, proximal, articular of 1, extra-articular of other (21-B3)

1. Ulna articular simple (21-B3.1)

- (1) radius extra-articular simple
- (2) radius extra-articular multifragmentary

2. Radius articular simple (21-B3.2)

- (1) ulna extra-articular simple
- (2) ulna extra-articular multifragmentary

3. Articular multifragmentary (21-B3.3)

- (1) ulna, radius extra-articular simple
- (2) ulna, radius extra-articular multifragmentary
- (3) radius, ulna extra-articular simple
- (4) radius, ulna extra-articular multifragmentary

B3



Radius/ulna, proximal, articular both simple (21-C1)

1. Olecranon and radial head (21-C1.1)

2. Coronoid process and radial head (21-C1.2)

C1



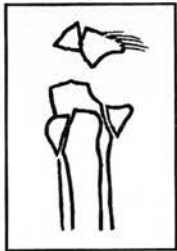
Radius/ulna, proximal, articular, both bones, 1 simple the other multifragmentary (21-C2)

1. Olecranon multifragmentary, radial head, simple (21-C2.1)

2. Olecranon simple, radial head multifragmentary (21-C2.2)

3. Coronoid process simple, radial head multifragmentary (21-C2.3)

C2



Radius/ulna, proximal, articular multifragmentary both bones (21-C3)

1. 3 fragments both bones (21-C3.1)

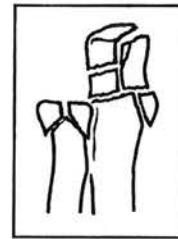
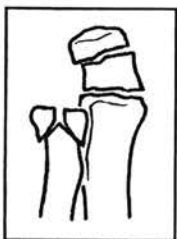
2. Ulna, more than 3 fragments (21-C3.2)

3. Radius, more than 3 fragments (21-C3.3)

(1) radius, 3 fragments
(2) radius, more than 3 fragments

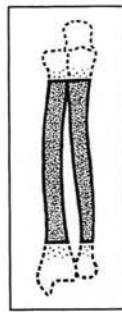
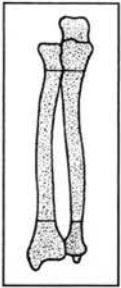
(1) ulna, 3 fragments
(2) ulna, epiphysio-diaphyseal

C3



BONE: RADIUS/ULNA (2)

Location: Diaphyseal (22)



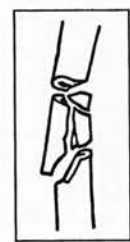
Types:
A. Simple (22-A)



B. Wedge (22-B)



C. Complex (22-C)



Groups:

Radius/ulna, diaphyseal, simple (22-A)

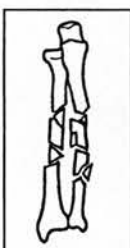
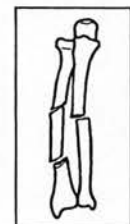
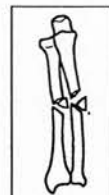
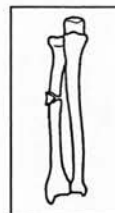
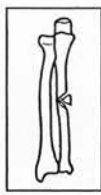
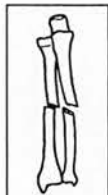
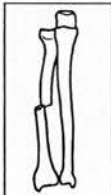
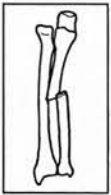
- 1. Ulna simple, radius intact (22-A1)
- 2. Radius simple, ulna intact (22-A2)
- 3. Simple fracture both bones (22-A3)

Radius/ulna, diaphyseal, wedge fracture (22-B)

- 1. Ulna fracture, radius intact (22-B1)
- 2. Radius fracture, ulna intact (22-B2)
- 3. Wedge fracture, simple or wedge of other bone (22-B3)

Radius/ulna, diaphyseal, complex (22-C)

- 1. Complex of ulna (22-C1)
- 2. Complex of radius (22-C2)
- 3. Complex of both bones (22-C3)



Subgroups and Qualifications:

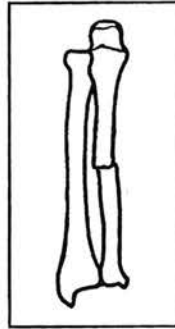
Radius/ulna, diaphyseal, simple fracture of ulna (22-A1)

1. Oblique (22-A1.1)

2. Transverse (22-A1.2)

3. With dislocation of radial head (Monteggia) (22-A1.3)

A1



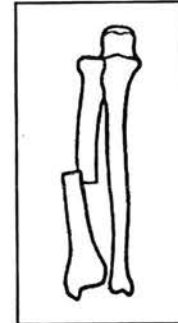
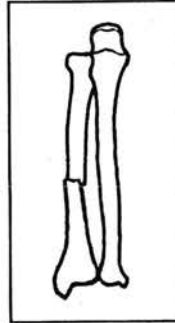
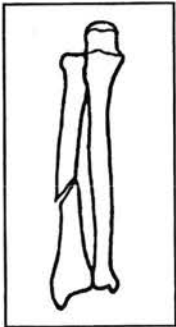
Radius/ulna, diaphyseal, simple fracture of radius (22-A2)

1. Oblique (22-A2.1)

2. Transverse (22-A2.2)

3. With dislocation of distal radio-ulnar joint (Galeazzi) (22-A2.3)

A2



Radius/ulna, diaphyseal, simple fracture of both bones (22-A3)

(1) without dislocation

(2) with dislocation of radial head (Monteggia)

(3) with dislocation of distal radioulnar joint (Galeazzi)

(based on level of radial fracture)

1. Radius, proximal zone (22-A3.1)

2. Radius, middle zone (22-A3.2)

3. Radius, distal zone (22-A3.3)

A3



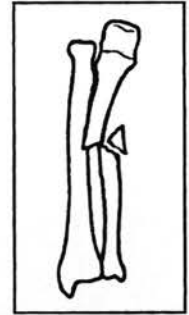
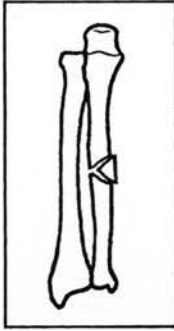
Radius/ulna, diaphyseal, wedge fracture of ulna (22-B1)

1. Intact wedge (22-B1.1)

2. Fragmented wedge (22-B1.2)

3. With dislocation of radial head (Monteggia) (22-B1.3)

B1



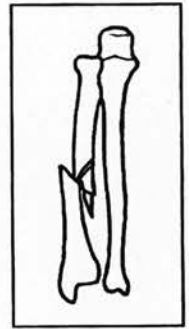
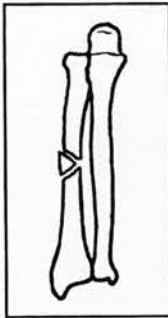
Radius/ulna, diaphyseal, wedge fracture of radius (22-B2)

1. Intact wedge (22-B2.1)

2. Fragmented wedge (22-B2.2)

3. With dislocation of distal radio-ulnar joint (Galeazzi) (22-B2.3)

B2



Radius/ulna, diaphyseal, wedge of 1, simple or wedge of other (22-B3)

(1) without dislocation

(2) with dislocation of radial head (Monteggia)

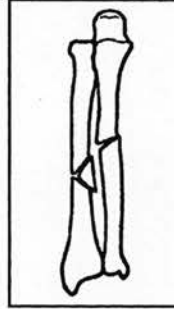
(3) with dislocation of distal radioulnar joint (Galeazzi)

1. Ulna wedge, simple fracture radius (22-B3.1)

2. Radial wedge, simple fracture of ulna (22-B3.2)

3. Radial and ulnar wedge (22-B3.3)

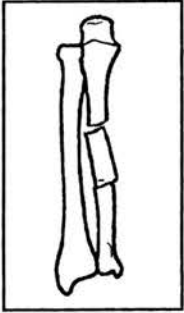
B3



Radius/ulna, diaphyseal, complex fracture of ulna (22-C1)

1. Bifocal, radius intact (22-C1.1)

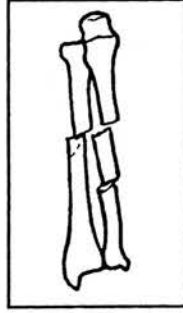
- (1) without dislocation
- (2) with radial head dislocated (Monteggia)



C1

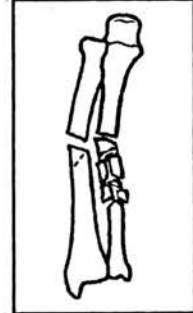
2. Bifocal with radial fracture (22-C1.2)

- (1) radius simple
- (2) radius wedge



3. Irregular of ulna (22-C1.3)

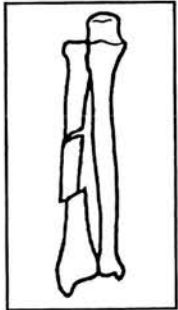
- (1) radius intact
- (2) radius simple
- (3) radius wedge



Radius/ulna, diaphyseal, complex fracture of radius (22-C2)

1. Bifocal, ulna intact (22-C2.1)

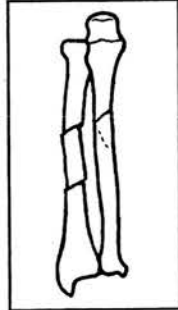
- (1) without dislocation
- (2) with dislocation of distal radioulnar joint (Galeazzi)



C2

2. Bifocal, ulna fracture (22-C2.2)

- (1) simple ulna
- (2) wedge ulna



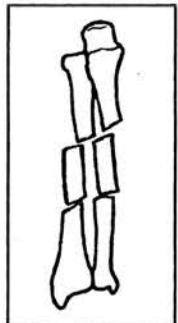
3. Irregular (22-C2.3)

- (1) ulna intact
- (2) ulna simple
- (3) ulna wedge



Radius/ulna, diaphyseal, complex of both bones (22-C3)

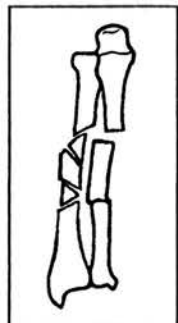
1. Bifocal (22-C3.1)



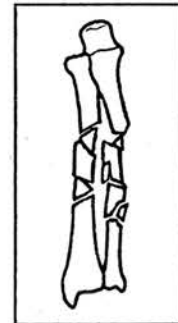
C3

2. Bifocal of 1, irregular of other (22-C3.2)

- (1) bifocal radius, irregular ulna
- (2) bifocal ulna, irregular radius

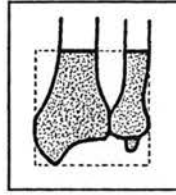
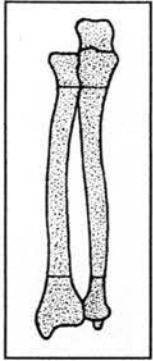


3. Irregular (22-C3.3)



BONE: RADIUS/ULNA (2)

Location: Distal segment (23)

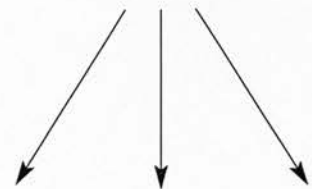
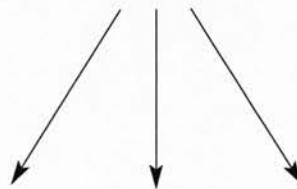
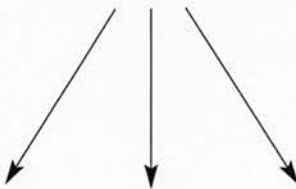
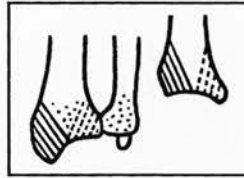


Types:

A. Extra-articular (23-A)

B. Partial articular fracture of radius (23-B)

C. Complete articular fracture of radius (23-C)



Groups:

Radius/ulna, distal, extra-articular (23-A)

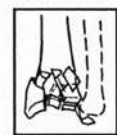
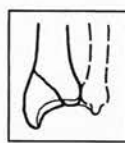
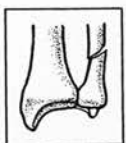
- 1. Extra-articular ulna fracture, radius intact (23-A1)
- 2. Extra-articular simple radius fracture, ulna intact (23-A2)
- 3. Extra-articular, multifragmentary radius fracture (23-A3)

Radius/ulna, distal, partial articular radius (23-B)

- 1. Partial articular radius, ulnar radius, sagittal (23-B1)
- 2. Partial articular radius, dorsal rim (Barton) (23-B2)
- 3. Partial articular radius, volar rim (reverse Barton, Goyrand Smith II) (23-B3)

Radius/ulna, distal, complete articular (23-C)

- 1. Complete articular radius, simple articular and metaphysis (23-C1)
- 2. Complete articular radius, simple articular, metaphyseal multifragmentary (23-C2)
- 3. Complete articular radius, multifragmentary (23-C3)



Subgroups and Qualifications:

Radius/ulna, distal, extra-articular fracture of ulna (23-A1)

1. Ulna styloid process (23-A1.1)

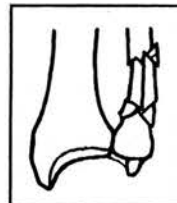
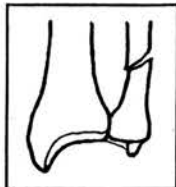
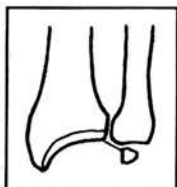
2. Metaphyseal simple (23-A1.2)

3. Metaphyseal multifragmentary (23-A1.3)

(1) wedge

(2) complex

A1



Radius/ulna, distal, extra-articular fracture of radius, simple metaphyseal and impacted (23-A2)

(1) radioulnar dislocation (fracture of styloid process)

(2) simple fracture of ulnar neck

(3) multifragmentary fracture of ulnar neck

(4) fracture of ulna head

(5) fracture of ulna head and neck

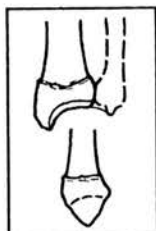
(6) fracture proximal to ulnar neck

1. Transverse, no tilt, but may be axially shortened (23-A2.1)

2. With dorsal tilt, oblique fracture upward and back (Pouteau-Colles) (23-A2.2)

3. Volar tilt, oblique upwards and forward (Goyrand-Smith) (23-A2.3)

A2



Radius/ulna, distal, extra-articular fracture of radius, multifragmentary (23-A3)

(1) radioulnar dislocation (fracture of styloid process)

(2) simple fracture of ulnar neck

(3) multifragmentary fracture of ulnar neck

(4) fracture of ulna head

(5) fracture of ulna head and neck

(6) fracture proximal to ulnar neck

1. Impacted with axial shortening (23-A3.1)

2. With a wedge (23-A3.2)

3. Complex (23-A3.3)

A3

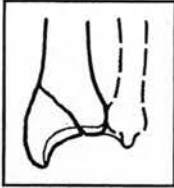


Radius/ulna, distal, partial articular fracture of radius, sagittal (23-B1)

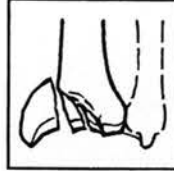
- (1) radioulnar dislocation (fracture of styloid process)
- (2) simple fracture of ulnar neck
- (3) multifragmentary fracture of ulnar neck
- (4) fracture of ulna head
- (5) fracture of ulna head and neck
- (6) fracture proximal to ulnar neck

1. Lateral simple (23-B1.1)

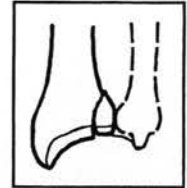
B1



2. Lateral multifragmentary (23-B1.2)



3. Medial (23-B1.3)



Radius/ulna, distal, partial articular fracture of radius, dorsal rim (Barton's) (23-B2)

- (1) radioulnar dislocation (fracture of styloid process)
- (2) simple fracture of ulnar neck
- (3) multifragmentary fracture of ulnar neck
- (4) fracture of ulna head
- (5) fracture of ulna head and neck
- (6) fracture proximal to ulnar neck

1. Simple (23-B2.1)

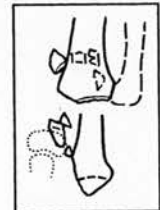
B2



2. With lateral sagittal fracture (23-B2.2)



3. With dorsal dislocation of carpus (23-B2.3)



Radius/ulna, distal, partial articular fracture of radius, volar rim (reverse Barton's, Goyrand-Smith II) (23-B3)

- (1) radioulnar dislocation (fracture of styloid process)
- (2) simple fracture of ulnar neck
- (3) multifragmentary fracture of ulnar neck
- (4) fracture of ulna head
- (5) fracture of ulna head and neck
- (6) fracture proximal to ulnar neck

1. Simple with small fragment (23-B3.1)

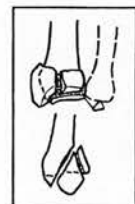
B3



2. Simple with larger fragment (23-B3.2)



3. Multifragmentary (23-B3.3)



Radius/ulna, distal, complete articular fracture of radius, articular simple, metaphyseal simple (23-C1)

- (1) radioulnar dislocation (fracture of styloid process)
- (2) simple fracture of ulnar neck
- (3) multifragmentary fracture of ulnar neck
- (4) fracture of ulna head
- (5) fracture of ulna head and neck
- (6) fracture proximal to ulnar neck

1. Posteromedial articular fragment (23-C1.1)

C1



2. Sagittal articular fracture line (23-C1.2)



3. Frontal articular fracture line (23-C1.3)

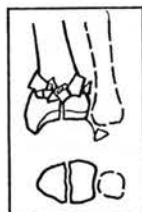


Radius/ulna, distal, complete articular fracture of radius, articular simple, metaphyseal multifragmentary (23-C2)

- (1) radioulnar dislocation (fracture of styloid process)
- (2) simple fracture of ulnar neck
- (3) multifragmentary fracture of ulnar neck
- (4) fracture of ulna head
- (5) fracture of ulna head and neck
- (6) fracture proximal to ulnar neck

1. Sagittal articular fracture line (23-C2.1)

C2



2. Frontal articular fracture line (23-C2.2)



3. Extending into diaphysis (23-C2.3)



Radius/ulna, distal, complete articular fracture of radius, multifragmentary (23-C3)

- (1) radioulnar dislocation (fracture of styloid process)
- (2) simple fracture of ulnar neck
- (3) multifragmentary fracture of ulnar neck
- (4) fracture of ulna head
- (5) fracture of ulna head and neck
- (6) fracture proximal to ulnar neck

1. Metaphyseal simple (23-C3.1)

C3



2. Metaphyseal multifragmentary (23-C3.2)

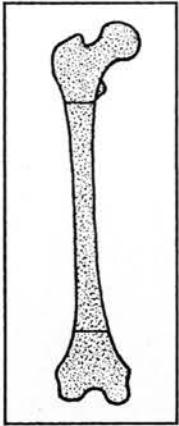


3. Extending into diaphysis (23-C3.3)

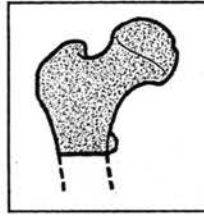


FEMUR

BONE: FEMUR (3)



Location: Proximal segment (31)



Types:

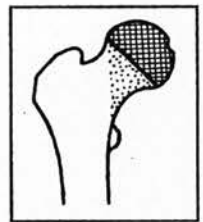
A. Trochanteric area (31-A)



B. Neck fractures (31-B)



C. Head fractures (31-C)



Groups:

Femur, proximal trochanteric (31-A)

1. Perto-
chanteric simple
(31-A1)

2. Perto-
chanteric
multifrag-
mentary
(31-A2)

3. Intertro-
chanteric
(31-A3)

Femur, proximal, neck fracture (31-B)

1. Subcapital
with slight
displacement
(31-B1)

2. Transcer-
vical (31-B2)

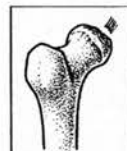
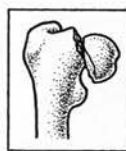
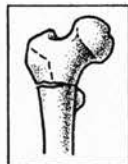
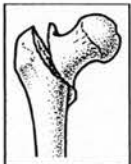
3. Subcapital
with marked
displacement
(31-B3)

Femur, proximal, head fracture (31-C)

1. Split (31-C1)

2. With de-
pression
(31-C2)

3. With neck
fracture
(31-C3)



Subgroups and Qualifications:

Femur, proximal, pertrochanteric simple (only 2 fragments) (31-A1)

1. Along intertrochanteric line
(31-A1.1)

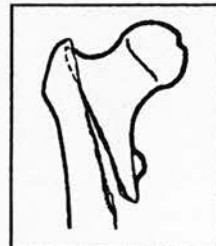
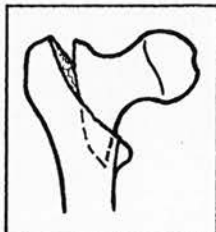
2. Through the greater trochanter
(31-A1.2)

(1) nonimpacted
(2) impacted

3. Below lesser trochanter (31-A1.3)

(1) high variety, medial fracture line at lower limit of lesser trochanter
(2) low variety, medial fracture line in diaphysis below lesser trochanter

A1



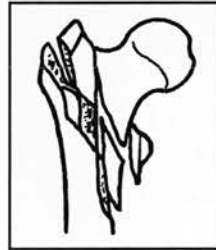
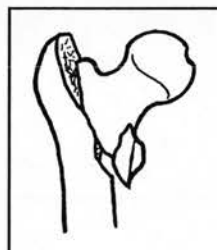
Femur proximal, trochanteric fracture, pertrochanteric multifragmentary (always have posteromedial fragment with lesser trochanter and adjacent medial cortex) (31-A2)

1. With 1 intermediate fragment
(31-A2.1)

2. With several intermediate fragments (31-A2.2)

3. Extending more than 1 cm below lesser trochanter (31-A2.3)

A2



Femur, proximal, trochanteric area, intertrochanteric fracture (31-A3)

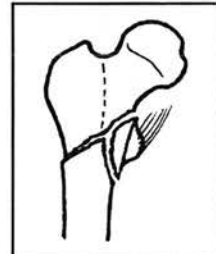
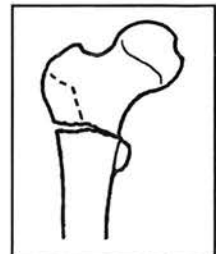
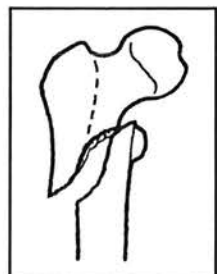
1. Simple oblique (31-A3.1)

2. Simple transverse (31-A3.2)

3. Multifragmentary (31-A3.3)

(1) extending to greater trochanter
(2) extending to neck

A3



Femur, proximal, neck fracture, slight displacement (31-B1)

1. Impacted in valgus $\geq 15^\circ$

(31-B1.1) (Garden 1)

(1) posterior tilt $< 15^\circ$

(2) posterior tilt $> 15^\circ$

2. Impacted in valgus $< 15^\circ$

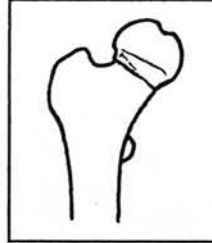
(31-B1.2) (Garden 1/2)

(1) posterior tilt $< 15^\circ$

(2) posterior tilt $> 15^\circ$

3. Nonimpacted (31-B1.3) (Garden 2)

B1



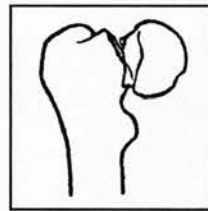
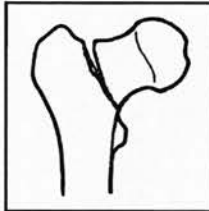
Femur, proximal, neck fracture, transcervical (31-B2)

1. Basicervical (31-B2.1)

2. Midcervical adduction (31-B2.2)

3. Midcervical shear (31-B2.3)

B2



Femur, proximal, neck fracture, sub-capital, nonimpacted displaced (31-B3)

1. Moderate displacement in varus and external rotation (31-B3.1) (Garden 3)

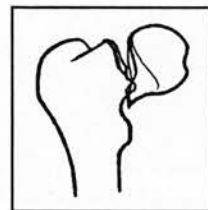
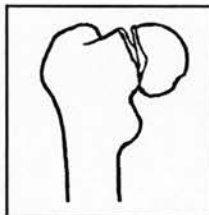
2. Moderate displacement with vertical translation and external rotation (31-B3.2) (Garden 4)

3. Marked displacement (31-B3.3) (Garden 3/4)

(1) in varus

(2) with translation

B3



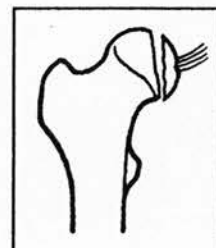
Femur, proximal, head fracture, split (31-C1)

1. Avulsion of ligamentum teres (31-C1.1)

2. With rupture of ligamentum teres (31-C1.2)

3. Large fragment (31-C1.3)

C1



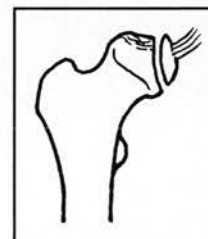
Femur, proximal, head fracture, with depression (31-C2)

1. Posterior and superior (31-C2.1)

2. Anterior and superior (31-C2.2)

3. Split depression (31-C2.3)

C2



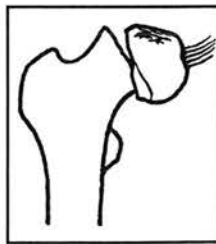
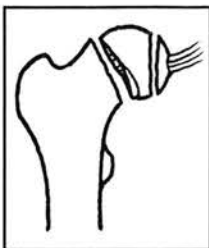
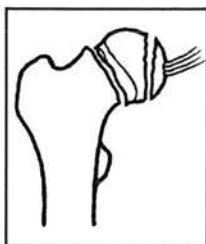
Femur, proximal, head fracture with neck fracture (31-C3)

1. Split and transcervical neck fracture (31-C3.1)

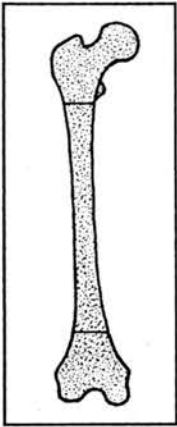
2. Split and subcapital neck fracture (31-C3.2)

3. Depression and neck fracture (31-C3.3)

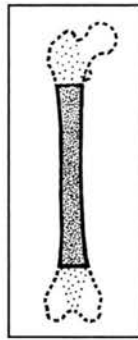
C3



BONE: FEMUR (3)

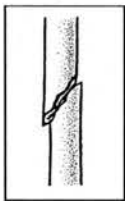


Location: Diaphyseal segment (32)



Types:

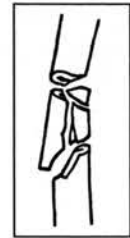
A. Simple (32-A)



B. Wedge (32-B)



C. Complex (32-C)



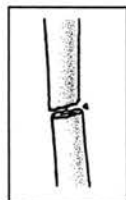
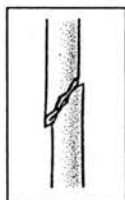
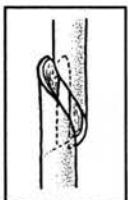
Groups:

Femur, diaphyseal, simple fracture (32-A)

1. Spiral (32-A1)

2. Oblique ($\geq 30^\circ$) (32-A2)

3. Transverse ($< 30^\circ$) (32-A3)

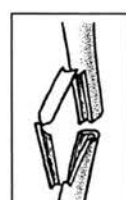
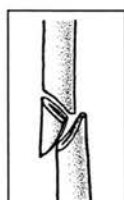


Femur, diaphyseal, wedge fracture (32-B)

1. Spiral wedge (32-B1)

2. Bending wedge (32-B2)

3. Fragmented wedge (32-B3)

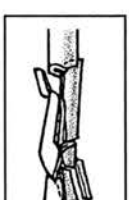
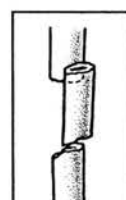


Femur, diaphyseal, complex (32-C)

1. Spiral (32-C1)

2. Segmental (32-C2)

3. Irregular (32-C3)



Subgroups and Qualifications:

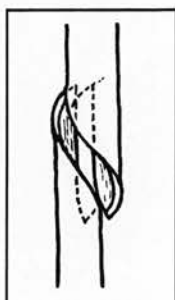
Femur, diaphyseal, simple spiral (32-A1)

1. Subtrochanteric zone (32-A1.1)

2. Middle zone (32-A1.2)

3. Distal zone (32-A1.3)

A1



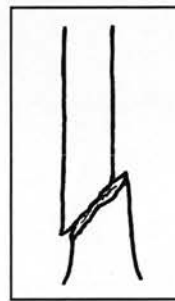
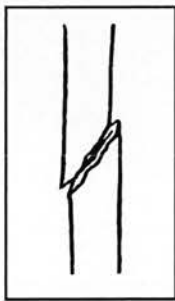
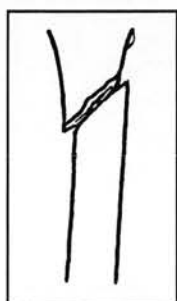
Femur, diaphyseal, simple oblique ($\geq 30^\circ$) (32-A2)

1. Subtrochanteric zone (32-A2.1)

2. Middle zone (32-A2.2)

3. Distal zone (32-A2.3)

A2



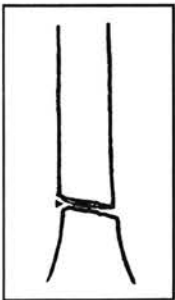
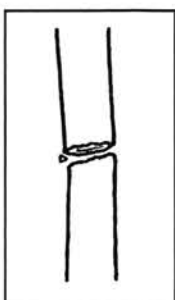
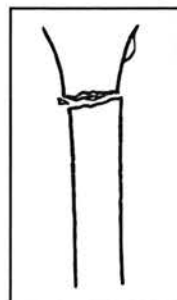
Femur, diaphyseal, transverse ($< 30^\circ$) (32-A3)

1. Subtrochanteric zone (32-A3.1)

2. Middle zone (32-A3.2)

3. Distal zone (32-A3.3)

A3



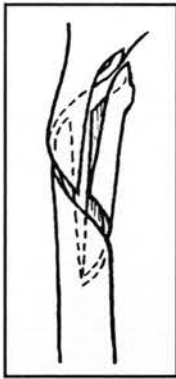
Femur, diaphyseal, wedge spiral (32-B1)

1. Subtrochanteric zone (32-B1.1)

2. Middle zone (32-B1.2)

3. Distal zone (32-B1.3)

B1



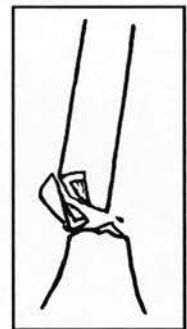
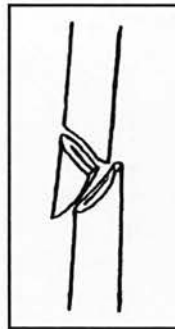
Femur, diaphyseal, wedge, bending (32-B2)

1. Subtrochanteric zone (32-B2.1)

2. Middle zone (32-B2.2)

3. Distal zone (32-B2.3)

B2



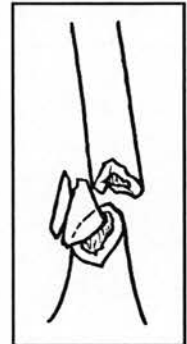
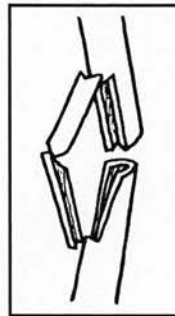
Femur, diaphyseal, wedge fragmented (32-B3)

1. Subtrochanteric zone (32-B3.1)

2. Middle zone (32-B3.2)

3. Distal zone (32-B3.3)

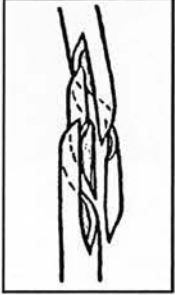
B3



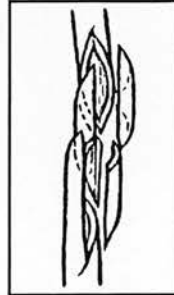
Femur, diaphyseal, complex spiral (32-C1)

- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal
- 1. With 2 intermediate fragments (32-C1.1)**

C1



- 2. With 3 intermediate fragments (32-C1.2)**



- 3. With more than 3 intermediate fragments (32-C1.3)**

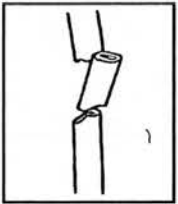


Femur, diaphyseal, complex segmental (32-C2)

- 1. With 1 intermediate segmental fracture (32-C2.1)**

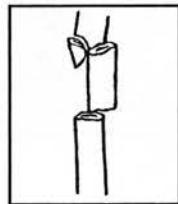
- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal
- (4) oblique lines
- (5) transverse and oblique lines

C2



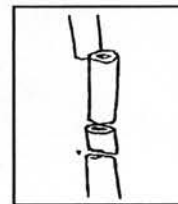
- 2. With 1 intermediate segmental and additional wedge fragments (32-C2.2)**

- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal
- (4) distal wedge
- (5) 2 wedges, proximal and distal



- 3. With 2 intermediate segmental fractures (32-C2.3)**

- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal

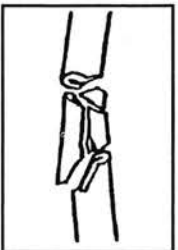


Femur, diaphyseal, complex irregular (32-C3)

- 1. With 2 or 3 intermediate fragments (32-C3.1)**

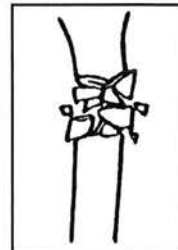
- (1) 2 main intermediate fragments
- (2) 3 main intermediate fragments

C3



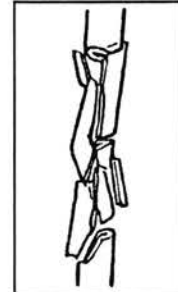
- 2. With limited shattering (<5cm) (32-C3.2)**

- (1) proximal zone
- (2) middle zone
- (3) distal zone

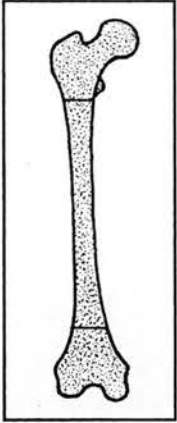


- 3. With extensive shattering (≥5cm) (32-C3.3)**

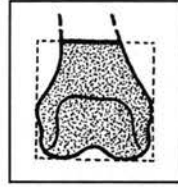
- (1) pure diaphyseal
- (2) proximal diaphysio-metaphyseal
- (3) distal diaphysio-metaphyseal



BONE: FEMUR (3)

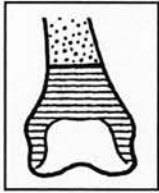


Location: Distal segment (33)



Types:

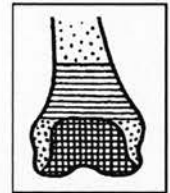
A. Extra-articular (33-A)



B. Partial articular (33-B)



C. Complete articular (33-C)



Groups:

Femur, distal, extra-articular (33-A)

1. Simple (33-A1)

2. Meta-
physeal
wedge
(33-A2)

3. Metaphyseal
complex
(33-A3)

Femur, distal, partial articular (33-B)

1. Lateral
condyle,
sagittal (33-B1)

2. Medial
condyle,
sagittal
(33-B2)

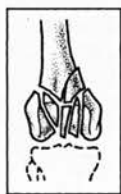
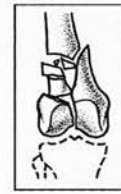
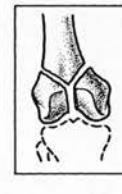
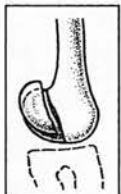
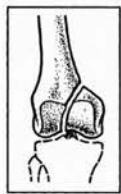
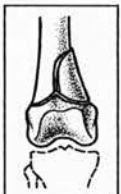
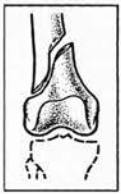
3. Frontal
(33-B3)

Femur, distal, complete articular (33-C)

1. Articular
simple, meta-
physeal simple
(33-C1)

2. Articular
simple, meta-
physeal multi-
fragmentary
(33-C2)

3. Multifrag-
mentary
articular
fracture
(33-C3)



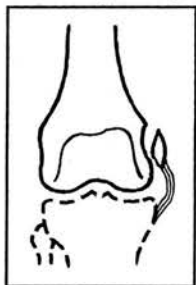
Subgroups and Qualifications:

Femur, distal, extra-articular simple (33-A1)

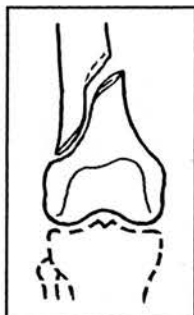
1. Apophyseal (33-A1.1)

- (1) avulsion lateral epicondyle
- (2) avulsion medial epicondyle

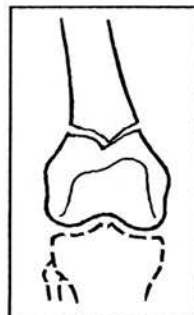
A1



2. Metaphyseal oblique or spiral (33-A1.2)



3. Metaphyseal transverse (33-A1.3)

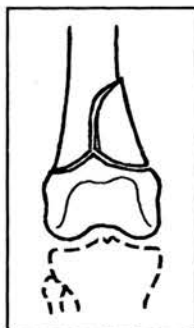


Femur, distal, extra-articular, metaphyseal wedge (33-A2)

1. Intact wedge (33-A2.1)

- (1) lateral
- (2) medial

A2



2. Fragmented lateral (33-A2.2)



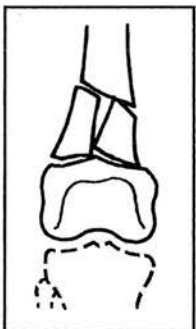
3. Fragmented medial (33-A2.3)



Femur, distal, extra-articular, metaphyseal complex (33-A3)

1. With an intermediate split segment (33-A3.1)

A3



2. Irregular limited to metaphysis (33-A3.2)



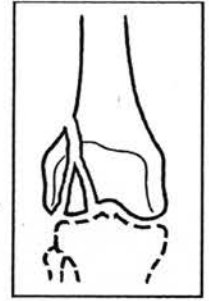
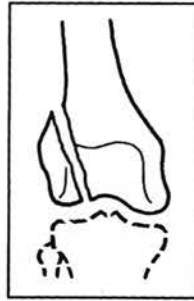
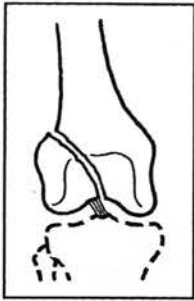
3. Irregular extending to diaphysis (33-A3.3)



Femur, distal, partial articular, lateral condyle, sagittal (33-B1)

1. Simple through the notch (33-B1.1) 2. Simple through load bearing surface (33-B1.2) 3. Multifragmentary (33-B1.3)

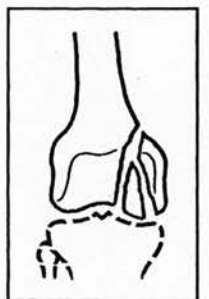
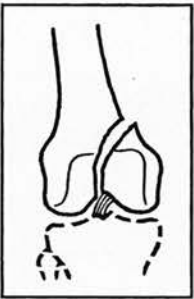
B1



Femur, distal, partial articular, medial condyle, sagittal (33-B2)

1. Simple through notch (33-B2.1) 2. Simple through load bearing surface (33-B2.2) 3. Multifragmentary (33-B2.3)

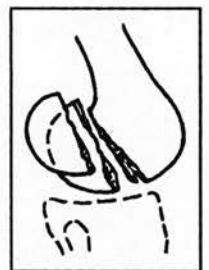
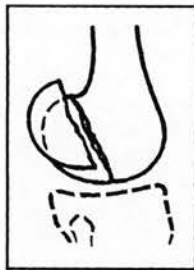
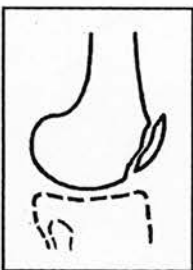
B2



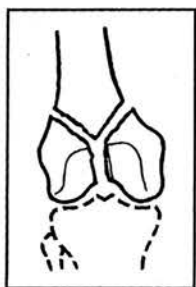
Femur, distal, partial articular, frontal (33-B3)

1. Anterior and lateral flake fracture (33-B3.1) 2. Unicondylar posterior (Hoffa) (33-B3.2) (1) lateral (2) medial 3. Bicondylar posterior (33-B3.3)

B3

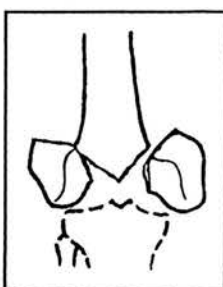


Femur, distal, complete articular, articular simple, metaphyseal simple (33-C1)
1. T- or Y-shaped with slight displacement (33-C1.1)

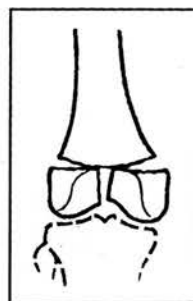


C1

2. T- or Y-shaped with marked displacement (33-C1.2)

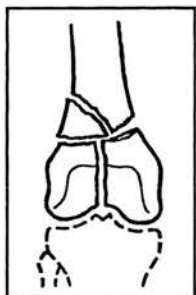


3. T-shaped epiphyseal (33-C1.3)



Femur, distal, complete articular, articular simple, metaphyseal multifragmentary (33-C2)

1. With intact wedge (33-C2.1)
(1) lateral
(2) medial



C2

2. With fragmented wedge (33-C2.2)
(1) lateral
(2) medial

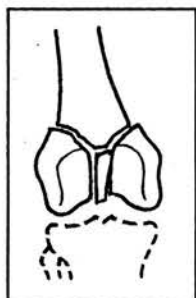


3. Complex (33-C2.3)



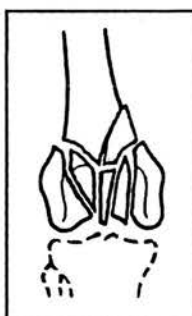
Femur, distal, complete articular, articular multifragmentary (33-C3)

1. Metaphyseal simple (33-C3.1)



C3

2. Metaphyseal multifragmentary (33-C3.2)

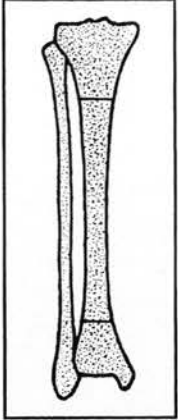


3. Metaphysio-diaphyseal multifragmentary (33-C3.3)

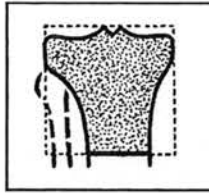


TIBIA/FIBULA

BONE: TIBIA/FIBULA (4)

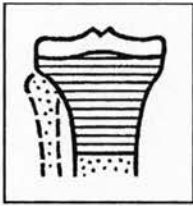


Location: Proximal segment (41)

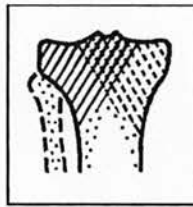


Types:

A. Extra-articular (41-A)



B. Partial articular (41-B)



C. Complete articular (41-C)



Groups:

Tibia/fibula, proximal, extra-articular (41-A)

1. Avulsion (41-A1)

2. Metaphyseal simple (41-A2)

3. Metaphyseal multifragmentary (41-A3)

Tibia/fibula, proximal, partial articular (41-B)

1. Pure split (41-B1)

2. Pure depression (41-B2)

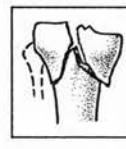
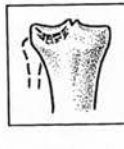
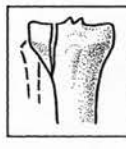
3. Split depression (41-B3)

Tibia/fibula, proximal, complete articular (41-C)

1. Articular simple, metaphyseal simple (41-C1)

2. Articular simple, metaphyseal multifragmentary (41-C2)

3. Articular multifragmentary (41-C3)



Subgroups and Qualifications:

Tibia/fibula, proximal, extra-articular, avulsion (41-A1)

1. Of fibular head (41-A1.1)

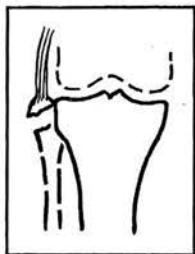
2. Of tibial tuberosity (41-A1.2)

3. Of cruciate insertion (41-A1.3)

(1) anterior

(2) posterior

A1



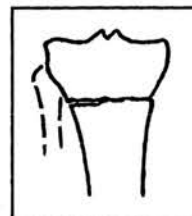
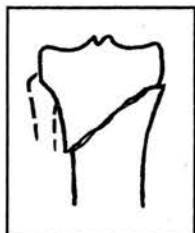
Tibia/fibula, proximal, extra-articular, simple metaphysis (41-A2)

1. Oblique in frontal plane (41-A2.1)

2. Oblique in sagittal plane (41-A2.2)

3. Transverse (41-A2.3)

A2



Tibia/fibula, proximal, extra-articular, multifragmentary metaphysis (41-A3)

1. Intact wedge (41-A3.1)

2. Fragmented wedge (41-A3.2)

3. Complex (41-A3.3)

(1) lateral

(2) medial

(1) lateral

(2) medial

(1) slightly displaced

(2) significantly displaced

A3



Tibia/fibula, proximal, partial articular, split (41-B1)

1. Of lateral surface (41-B1.1)

- (1) marginal
- (2) sagittal
- (3) frontal anterior
- (4) frontal posterior

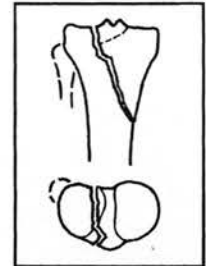
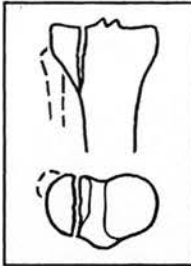
2. Of medial surface (41-B1.2)

- (1) marginal
- (2) sagittal
- (3) frontal anterior
- (4) frontal posterior

3. Oblique, involving the tibial spines and 1 of the surfaces (41-B1.3)

- (1) lateral
- (2) medial

B1



Tibia/fibula, proximal, partial articular, depression (41-B2)

1. Lateral total (41-B2.1)

- (1) 1 piece
- (2) mosaic-like

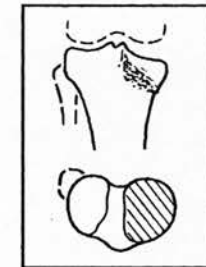
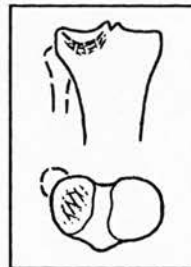
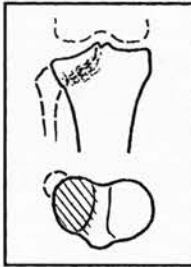
2. Lateral limited (41-B2.2)

- (1) peripheral
- (2) central
- (3) anterior
- (4) posterior

3. Medial (41-B2.3)

- (1) central
- (2) anterior
- (3) posterior
- (4) total

B2



Tibia/fibula, proximal, partial articular, split depression (41-B3)

1. Lateral (41-B3.1)

- (1) antero-lateral depression
- (2) postero-lateral depression
- (3) antero-medial depression
- (4) postero-medial depression

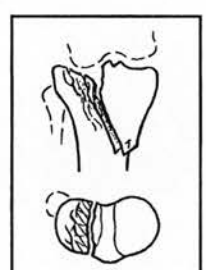
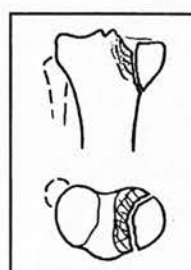
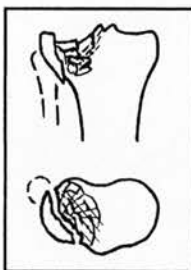
2. Medial (41-B3.2)

- (1) antero-lateral depression
- (2) postero-lateral depression
- (3) antero-medial depression
- (4) postero-medial depression

3. Oblique involving the tibial spines and 1 of the surfaces (41-B3.3)

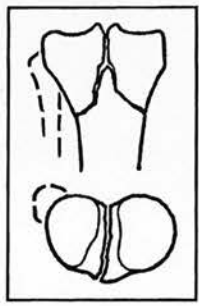

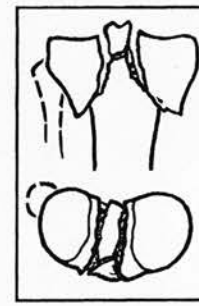
- (1) lateral
- (2) medial

B3



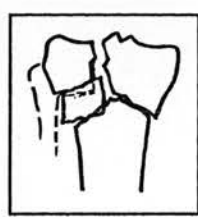

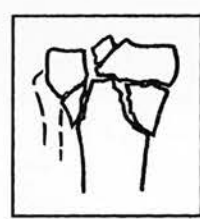
Tibia/fibula, proximal, complete articular, simple articular, simple metaphysis (41-C1)

- (1) intact anterior tibial tubercle and intercondylar eminence
- (2) anterior tibial tubercle involved
- (3) intercondylar eminence involved

C1	<p>1. Slight displacement (41-C1.1)</p> 	<p>2. 1 condyle displaced (41-C1.2)</p> 	<p>3. Both condyles displaced (41-C1.3)</p> 
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Tibia/fibula, proximal, complete articular, articular simple, metaphysis multifragmentary (41-C2)

- | | | |
|--|--|-----------------------------|
| <p>1. Intact wedge (41-C2.1)</p> <ul style="list-style-type: none"> (1) lateral (2) medial | <p>2. Fragmented wedge (41-C2.2)</p> <ul style="list-style-type: none"> (1) lateral (2) medial | <p>3. Complex (41-C2.3)</p> |
|--|--|-----------------------------|

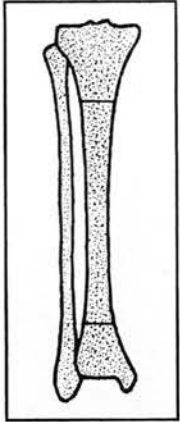
C2			
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Tibia/fibula, proximal, complete articular, articular multifragmentary (41-C3)

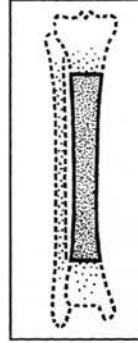
- (1) metaphyseal simple
- (2) metaphyseal lateral wedge
- (3) metaphyseal medial wedge
- (4) metaphyseal complex
- (5) metaphysio-diaphyseal complex

C3	<p>1. Lateral (41-C3.1)</p> 	<p>2. Medial (41-C3.2)</p> 	<p>3. Lateral and medial (41-C3.3)</p> 
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BONE: TIBIA/FIBULA (4)



Location: Diaphyseal segment (42)



Types:
A. Simple (42-A)



B. Wedge (42-B)



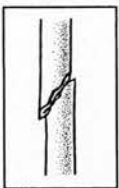
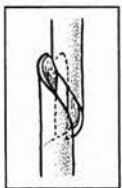
C. Complex (42-C)



Groups:

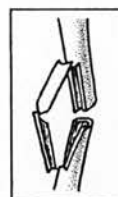
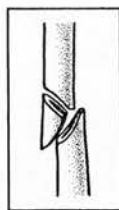
Tibia/fibula, diaphyseal, simple (42-A)

- 1. Spiral (42-A1)
- 2. Oblique ($\geq 30^\circ$) (42-A2)
- 3. Transverse ($< 30^\circ$) (42-A3)



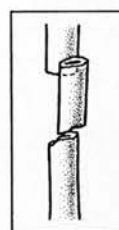
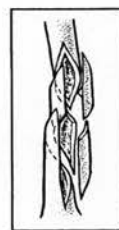
Tibia/fibula, diaphyseal, wedge (42-B)

- 1. Spiral wedge (42-B1)
- 2. Bending wedge (42-B2)
- 3. Fragmented wedge (42-B3)



Tibia/fibula, diaphyseal, complex (42-C)

- 1. Spiral (42-C1)
- 2. Segmented (42-C2)
- 3. Irregular (42-C3)

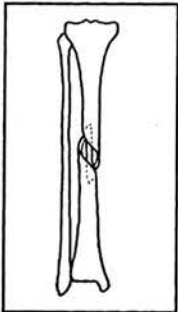


Subgroups and Qualifications:

Tibia/fibula, diaphyseal, simple, spiral (42-A1)

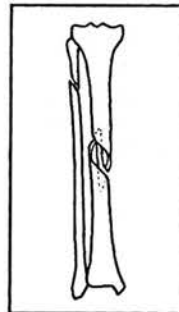
- (1) proximal zone
- (2) middle zone
- (3) distal zone

1. Fibula intact (42-A1.1)

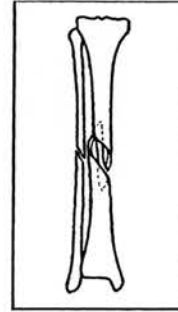


A1

2. Fibula fracture at different level (42-A1.2)



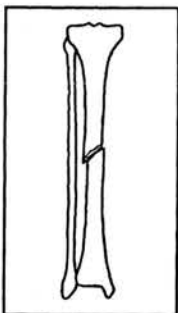
3. Fibula fracture at same level (42-A1.3)



Tibia/fibula, diaphyseal, simple, oblique ($\geq 30^\circ$) (42-A2)

- (1) proximal zone
- (2) middle zone
- (3) distal zone

1. Fibula intact (42-A2.1)

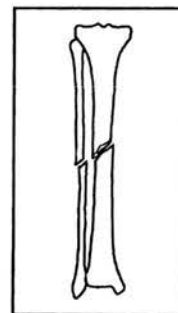


A2

2. Fibula fracture at different level (42-A2.2)



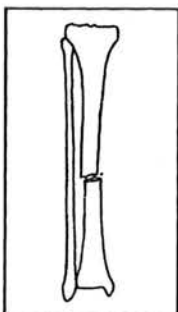
3. Fibula fracture at same level (42-A2.3)



Tibia/fibula, diaphyseal, simple, transverse ($< 30^\circ$) (42-A3)

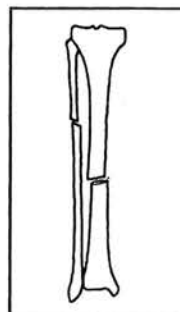
- (1) proximal zone
- (2) middle zone
- (3) distal zone

1. Fibula intact (42-A3.1)

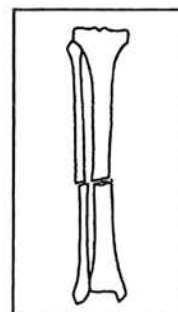


A3

2. Fibula fracture at different level (42-A3.2)



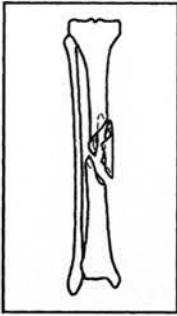
3. Fibula fracture at same level (42-A3.3)



Tibia/fibula, diaphyseal, wedge, spiral (42-B1)

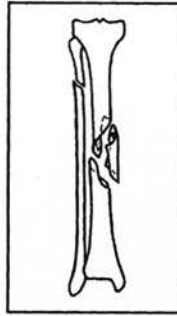
- (1) proximal zone
- (2) middle zone
- (3) distal zone

1. Fibula intact (42-B1.1)

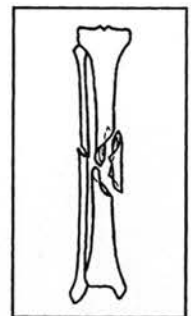


B1

2. Fibula fracture at different level (42-B1.2)



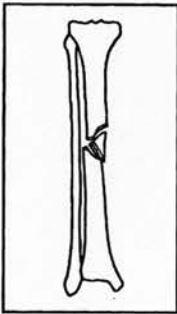
3. Fibula fracture at same level (42-B1.3)



Tibia/fibula, diaphyseal, wedge, bending (42-B2)

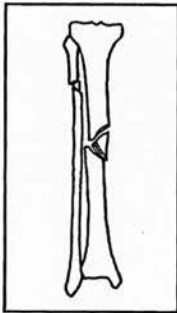
- (1) proximal zone
- (2) middle zone
- (3) distal zone

1. Fibula intact (42-B2.1)

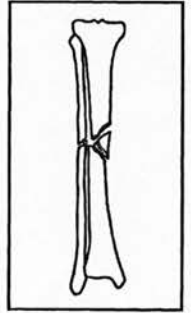


B2

2. Fibula fracture at different level (42-B2.2)



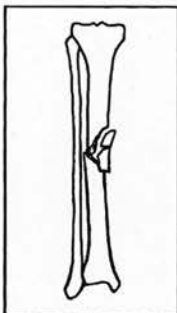
3. Fibula fracture at same level (42-B2.3)



Tibia/fibula, diaphyseal, wedge fragmented (42-B3)

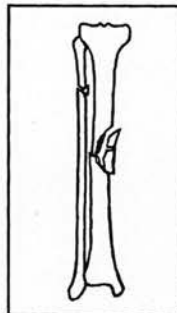
- (1) proximal zone
- (2) middle zone
- (3) distal zone

1. Fibula intact (42-B3.1)

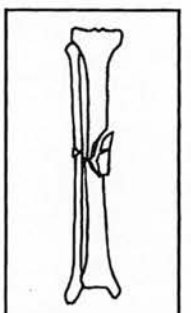


B3

2. Fibula fracture at different level (42-B3.2)



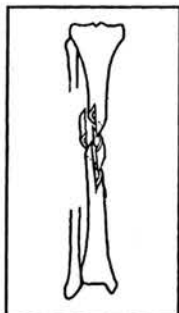
3. Fibula fracture at same level (42-B3.3)



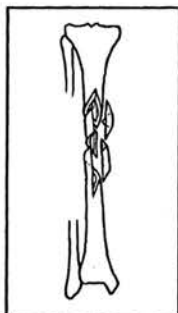
Tibia/fibula, diaphyseal, complex, spiral (42-C1)

- (1) pure diaphyseal
- (2) proximal diaphysis-metaphysis
- (3) distal diaphysis-metaphysis
- 1. With 2 intermediate fragments (42-C1.1)**

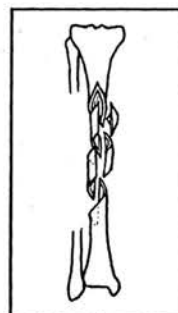
C1



- 2. With 3 intermediate fragments (42-C1.2)**



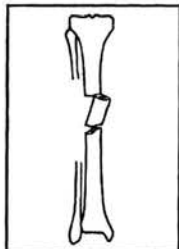
- 3. With more than 3 intermediate fragments (42-C1.3)**



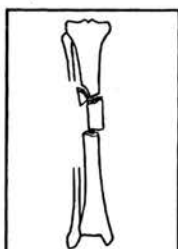
Tibia/fibula, diaphyseal, complex segmental (42-C2)

- 1. With an intermediate segmental fragment (42-C2.1)**
- (1) pure diaphyseal
- (2) proximal diaphysis-metaphyseal
- (3) distal diaphysis-metaphyseal
- (4) oblique lines
- (5) transverse and oblique lines

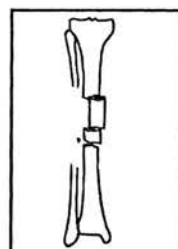
C2



- 2. With an intermediate segmental and additional wedge fragment(s) (42-C2.2)**
- (1) pure diaphyseal
- (2) proximal diaphysis-metaphyseal
- (3) distal diaphysis-metaphyseal
- (4) distal wedge
- (5) 3 wedges, proximal and distal



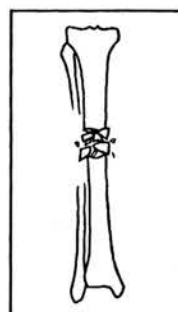
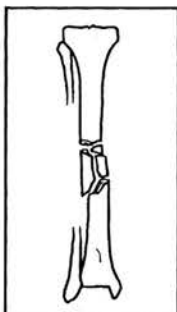
- 3. With 2 intermediate segmental fragments (42-C2.3)**
- (1) pure diaphyseal
- (2) proximal diaphysis-metaphyseal
- (3) distal diaphysis-metaphyseal



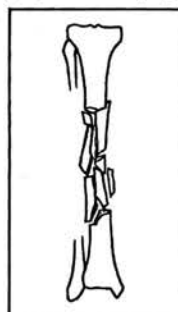
Tibia/fibula, diaphyseal, complex, irregular (42-C3)

- 1. With 2 or 3 intermediate fragments (42-C3.1)**
- (1) 2 intermediate fragments
- (2) 3 intermediate fragments
- 2. Limited shattering (<4cm) (42-C3.2)**

C3

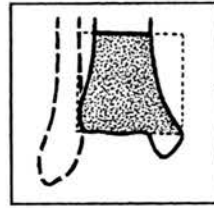
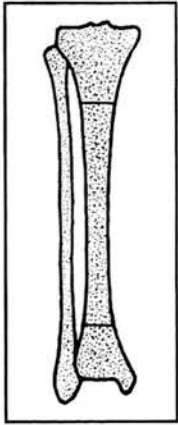


- 3. Extensive shattering (>4cm) (42-C3.3)**
- (1) pure diaphyseal
- (2) proximal diaphysis-metaphyseal
- (3) distal diaphysis-metaphyseal



BONE: TIBIA/FIBULA (4)

Location: Distal segment (43)

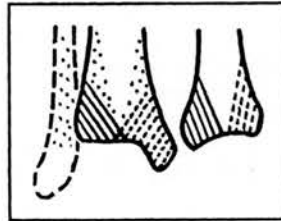
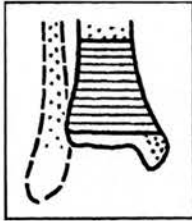


Types:

A. Extra-articular (43-A)

B. Partial articular (43-B)

C. Complete articular (43-C)



Groups:

Tibia/fibula, distal, extra-articular (43-A)

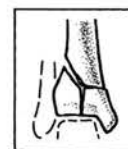
- 1. Metaphyseal simple (43-A1)
- 2. Metaphyseal wedge (43-A2)
- 3. Metaphyseal complex (43-A3)

Tibia/fibula, distal, partial articular (43-B)

- 1. Pure split (43-B1)
- 2. Split depression (43-B2)
- 3. Multifragmentary depression (43-B3)

Tibia/fibula, distal, complete articular (43-C)

- 1. Articular simple, metaphysis simple (43-C1)
- 2. Articular simple, metaphysis multifragmentary (43-C2)
- 3. Articular multifragmentary (43-C3)



Subgroups and Qualifications:

Tibia/fibula, distal, extra-articular, simple (43-A1)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

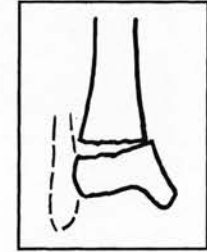
A1



2. Oblique (43-A1.2)



3. Transverse (43-A1.3)



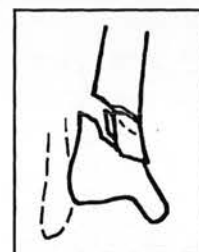
Tibia/fibula, distal, extra-articular, wedge (43-A2)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

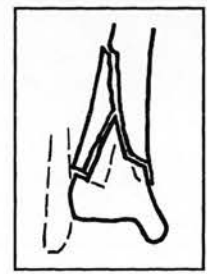
A2



2. Anteromedial wedge (43-A2.2)



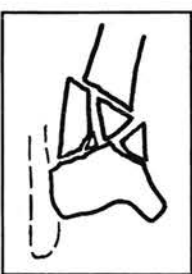
3. Extending into diaphysis (43-A2.3)



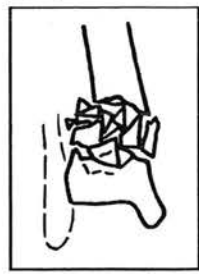
Tibia/fibula, distal, extra-articular, complex (43-A3)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

A3



2. More than 3 intermediate fragments (43-A3.2)



3. Extending into diaphysis (43-A3.3)



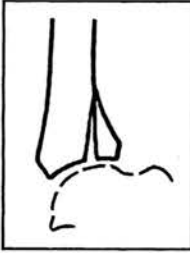
Tibia/fibula, distal, partial articular, pure split (43-B1)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

1. Frontal (43-B1.1)

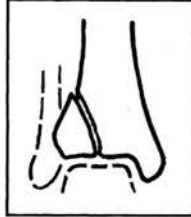
- (5) anterior
- (6) posterior (Volkman)

B1

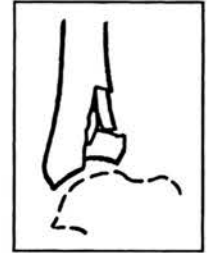


2. Sagittal (43-B1.2)

- (5) lateral
- (6) medial (medial malleolus)



3. Metaphyseal multifragmentary (43-B1.3)



Tibia/fibula, distal, partial articular, split depression (43-B2)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

1. Frontal (43-B2.1)

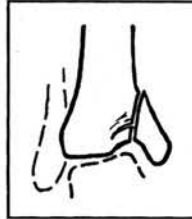
- (5) anterior
- (6) posterior

B2



2. Sagittal (43-B2.2)

- (5) lateral
- (6) medial



3. Of the central fragment (43-B2.3)



Tibia/fibula, distal, partial articular, depression (43-B3)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

1. Frontal (43-B3.1)

- (5) anterior
- (6) posterior

B3



2. Sagittal (43-B3.2)

- (5) lateral
- (6) medial



3. Metaphyseal, multifragmentary (43-B3.3)



Tibia/fibula, distal, complete articular, articular simple, metaphyseal simple (43-C1)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

1. Without impaction (43-C1.1)

- (5) frontal plane
- (6) sagittal plane

C1



2. With epiphyseal depression (43-C1.2)



3. Extending into diaphysis (43-C1.3)



Tibia/fibula, distal, complete articular, articular simple, multifragmentary metaphysis (43-C2)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

1. With asymmetric impaction (43-C2.1)

- (5) frontal plane split
- (6) sagittal plane split

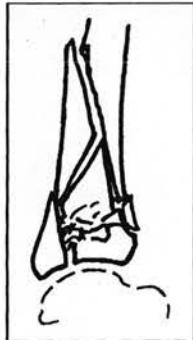
C2



2. Without asymmetric impaction (43-C2.2)



3. Extending into diaphysis (43-C2.3)



Tibia/fibula, distal, complete articular, articular multifragmentary (43-C3)

- (1) fibula intact
- (2) simple fracture of fibula
- (3) multifragmentary fracture of fibula
- (4) bifocal fracture of fibula

1. Epiphyseal (43-C3.1)

C3



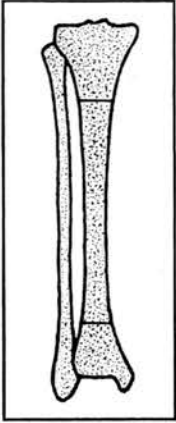
2. Epiphysio-metaphyseal (43-C3.2)



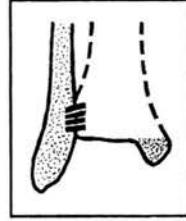
3. Epiphysio-metaphysio-diaphyseal (43-C3.3)



BONE: TIBIA/FIBULA (4)

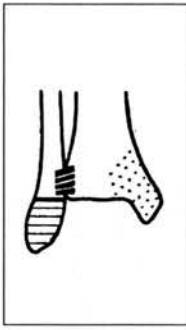


Location: Malleolar segment (44)

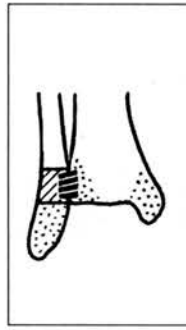


Types:

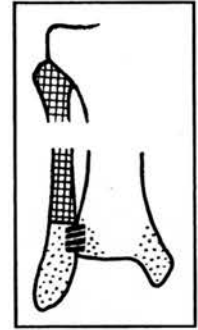
A. Infrasyndesmotc lesion (44-A)



B. Transsyndesmotc fibula fracture (44-B)



C. Suprasyndesmotc lesion (44-C)



Groups:

Tibia/fibula, malleolar, infrasyndesmotc lesions (44-A)

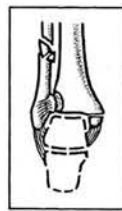
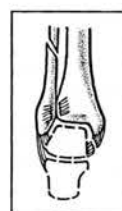
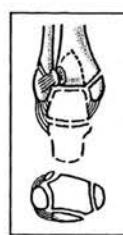
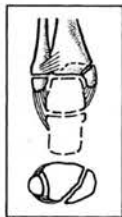
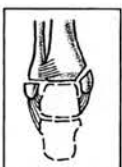
- 1. Isolated (44-A1)
- 2. With medial malleolar fracture (44-A2)
- 3. With postero-medial fracture (44-A3)

Tibia/fibula, malleolar, transsyndesmotc fibula fracture (44-B)

- 1. Isolated (44-B1)
- 2. With medial lesion (44-B2)
- 3. With medial lesion and Volkmann (fracture of the postero-lateral rim) (44-B3)

Tibia/fibula, malleolar, suprasyndesmotc (44-C)

- 1. Simple diaphyseal fibular fracture (44-C1)
- 2. Multifragmentary fracture of fibular diaphysis (44-C2)
- 3. Proximal fibula (44-C3)



Subgroups and Qualifications:

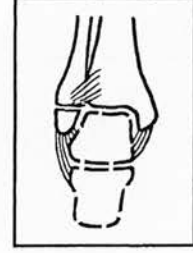
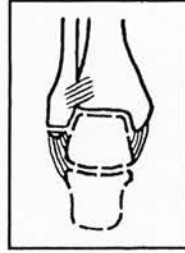
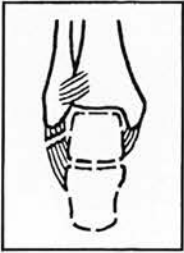
Tibia/fibula, malleolar, infrasyn-desmotic, isolated (44-A1)

1. Rupture of lateral collateral ligament (44-A1.1)

2. Avulsion of tip of lateral malleolus (44-A1.2)

3. Transverse fracture of lateral malleolus (44-A1.3)

A1



Tibia/fibula, malleolar, infrasyn-desmotic lesion with medial malleolar fracture (44-A2)

(1) transverse

(2) oblique

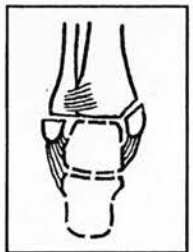
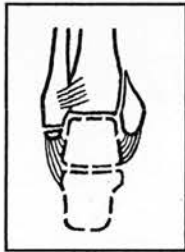
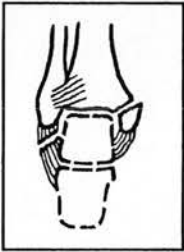
(3) vertical

1. Rupture of lateral collateral ligament (44-A2.1)

2. Avulsion of tip of lateral malleolus (44-A2.2)

3. Transverse fracture of lateral malleolus (44-A2.3)

A2



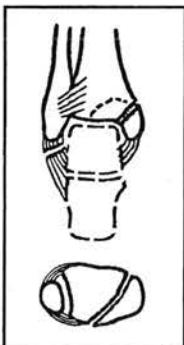
Tibia/fibula, malleolar, infrasyn-desmotic lesion with postero-medial fracture (44-A3)

1. Rupture of lateral collateral ligament (44-A3.1)

2. Avulsion of tip of lateral malleolus (44-A3.2)

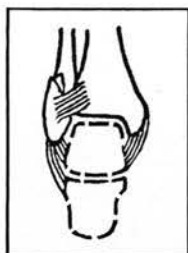
3. Transverse fracture of lateral malleolus (44-A3.3)

A3



Tibia/fibula, malleolar, transsyndesmotic, isolated (44-B1)

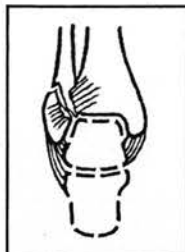
1. Simple (44-B1.1)



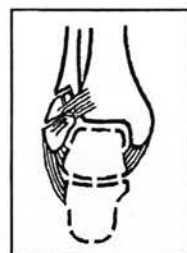
B1

2. Simple with rupture of anterior syndesmosis (44-B1.2)

- (1) in substance
- (2) Chaput (anterior tibia)
- (3) Lefort (anterior fibula)



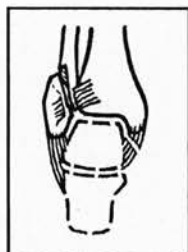
3. Multifragmentary (44-B1.3)



Tibia/fibula, malleolar, transsyndesmotic fracture with medial lesion (44-B2)

1. Simple, rupture of medial collateral and anterior syndesmosis (44-B2.1)

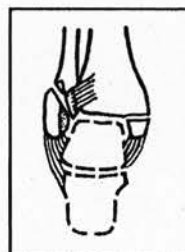
- (1) in substance
- (2) Chaput
- (3) Lefort



B2

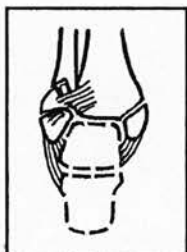
2. Simple with fracture of medial malleolus and rupture of anterior syndesmosis (44-B2.2)

- (1) in substance
- (2) Chaput
- (3) Lefort



3. Multifragmentary (44-B2.3)

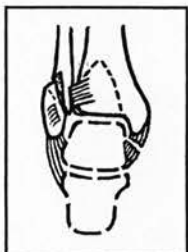
- (1) rupture of medial collateral ligament
- (2) fracture of medial malleolus



Tibia/fibula, malleolar, transsyndesmotic with medial lesion and a Volkmann (fracture of posterolateral rim) (44-B3)

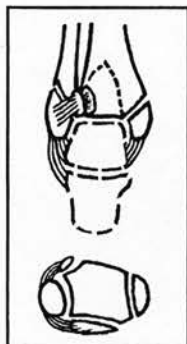
- (1) extra-articular avulsion
- (2) peripheral articular fragment
- (3) significant articular fracture

1. Fibula simple with medial collateral ligament rupture (44-B3.1)

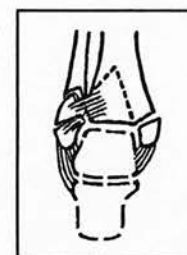


B3

2. Simple fibula fracture with fracture of medial malleolus (44-B3.2)



3. Multifragmentary with fracture of medial malleolus (44-B3.3)



Tibia/fibula, malleolar, suprasyndesmotic, simple diaphyseal fracture of fibula (44-C1)

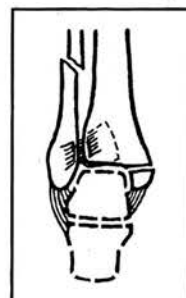
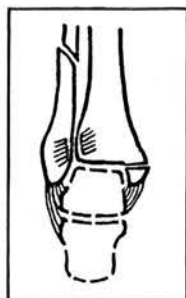
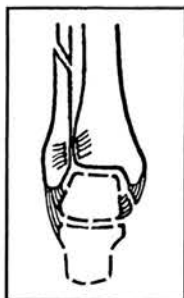
1. Rupture of medial collateral ligament (44-C1.1)

2. With fracture of medial malleolus (44-C1.2)

3. With fracture of medial malleolus and a Volkmann (Dupuytren) (44-C1.3)

- (1) extra-articular avulsion
- (2) peripheral articular fragment
- (3) significant articular fragment

C1



Tibia/fibula, malleolar, suprasyndesmotic, multifragmentary fibular diaphyseal fracture (44-C2)

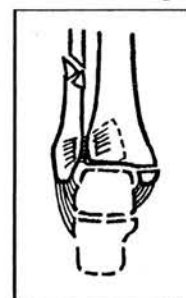
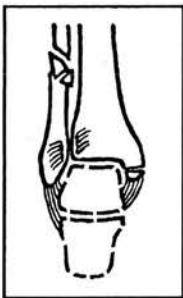
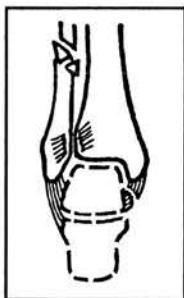
1. With rupture of medial collateral ligament (44-C2.1)

2. With fracture of medial malleolus (44-C2.2)

3. With fracture of medial malleolus and a Volkmann (Dupuytren) (44-C2.3)

- (1) extra-articular avulsion
- (2) peripheral articular fragment
- (3) significant articular fragment

C2



Tibia/fibula, malleolar, suprasyndesmotic, proximal fibular lesion (44-C3)

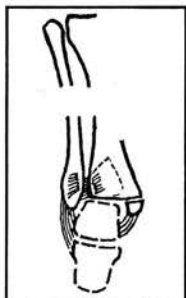
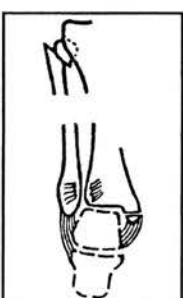
- (1) fracture through neck
- (2) fracture through head
- (3) proximal tibiofibular dislocation
- (4) rupture of medial collateral ligament
- (5) fracture of medial malleolus
- (6) articular fragment

1. Without shortening, without Volkmann (44-C3.1)

2. With shortening, without Volkmann (44-C3.2)

3. Medial lesion and a Volkmann (44-C3.3)

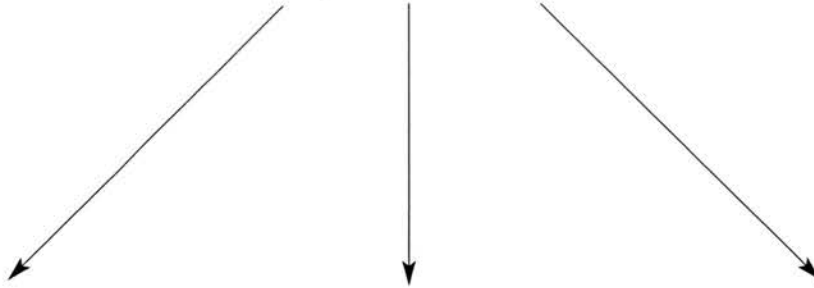
C3



PELVIS

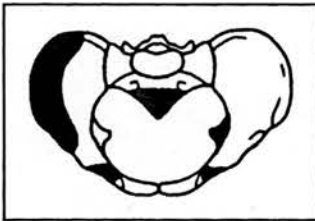
BONE: PELVIS (6)

Location: Pelvic ring (61)

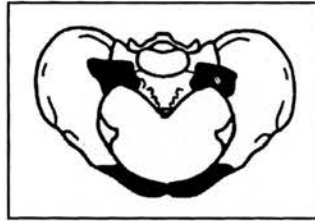


Types:

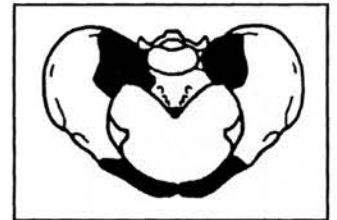
A. Lesion sparing (or with no displacement of) posterior arch (61-A)



B. Incomplete disruption of posterior arch, partially stable (61-B)



C. Complete disruption of posterior arch, unstable (61-C)



The classification of pelvic ring and acetabular fractures is based on the work of Pennal and Tile and Judet and Letournel. This classification was developed to accommodate the alpha-numeric system of The Comprehensive Long Bone System.

DEFINITIONS

Pelvic ring has two arches: (a) posterior arch is behind acetabular surface and includes sacrum, sacroiliac joints and their ligaments and posterior ilium, and (b) anterior arch is in front of acetabular surface and includes pubic rami bone and symphyseal joint.

Anterior column of acetabulum extends from the anterior half of the iliac crest to the pubis (iliopubic).

Posterior column of acetabulum extends from the greater sciatic notch to the ischium (ilioischial).

Unilateral: only 1 hemipelvis involved posteriorly.

Bilateral: both hemipelvis involved posteriorly.

Contralateral: the side opposite the major posterior lesion.

Ipsilateral: the side of the more severe lesion.

Stable: lesion sparing the posterior arch; pelvic floor intact and able to withstand normal physiological stresses without displacement.

Partially stable: posterior osteoligamentous integrity partially maintained and pelvic floor intact.

Unstable: complete loss of posterior osteoligamentous integrity; pelvic floor disrupted.

Where appropriate, the Young-Burgess classification has been added to the Subgroup and Qualification section. Although these terms are not part of the alpha-numeric code, they are added so that those using this classification can easily code into the alpha-numeric system for documentation. The following are the definitions of the Young-Burgess System:

APC: anterior-posterior compression; LC: lateral compression; SI: sacroiliac; VS: vertical shear; CMI: combined mechanical instability.

ACKNOWLEDGEMENTS

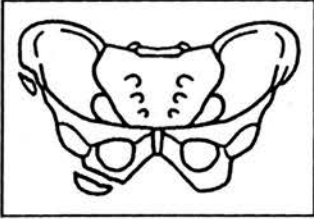
The O.T.A. Coding and Classification Committee gratefully acknowledges the following individuals for their significant contributions to the development of systematic universal pelvic and acetabular classifications:

Emile Letournel, MD; Marvin Tile, MD; Balz Isler, MD; David Helfet, MD; Serge Nazarian, MD

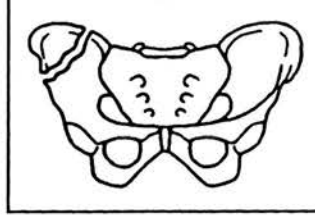
Groups:

Pelvis, ring, stable (61-A)

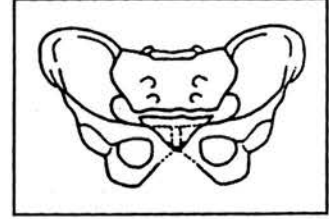
1. Fracture of innominate bone, avulsion (61-A1)



2. Fracture of innominate bone, direct blow (61-A2)

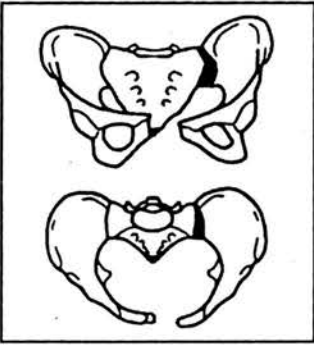


3. Transverse fracture of sacrum and coccyx (61-A3)

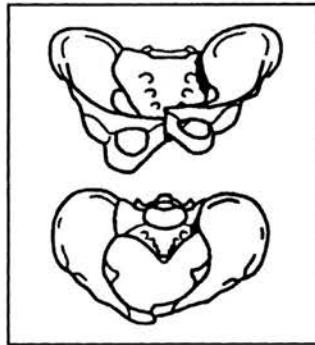


Pelvis, ring, partially stable (61-B)

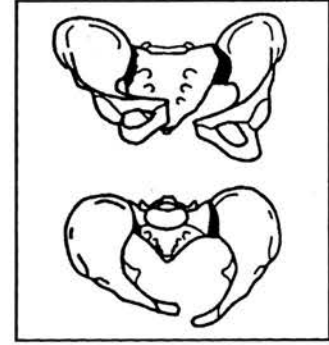
1. Unilateral, partial disruption of posterior arch, external rotation ("open-book" injury) (61-B1)



2. Unilateral, partial disruption of posterior arch, internal rotation (lateral compression injury) (61-B2)

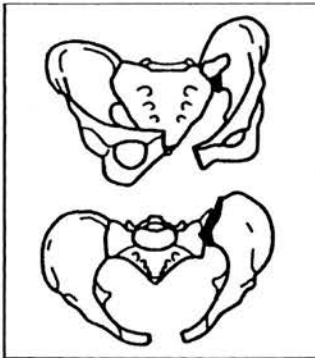


3. Bilateral, partial lesion of posterior arch (61-B3)

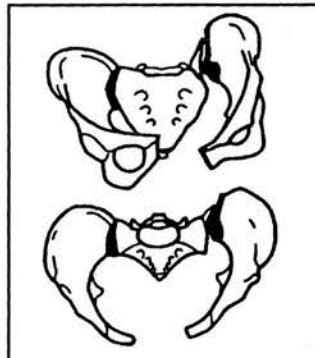


Pelvis, ring, complete disruption of posterior arch unstable (61-C)

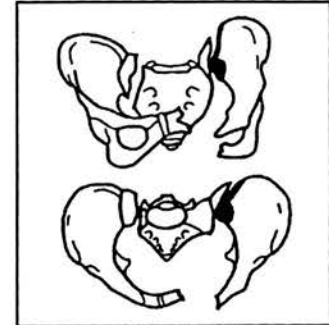
1. Unilateral, complete disruption of posterior arch (61-C1)



2. Bilateral, ipsilateral complete, contralateral incomplete (61-C2)



3. Bilateral, complete disruption (61-C3)



Subgroups and Qualifications:

Pelvis, ring, stable, avulsion of innominate bone (61-A1)

1. Iliac spine (61-A1.1)

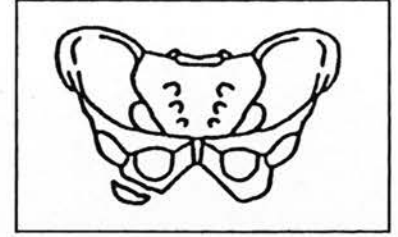
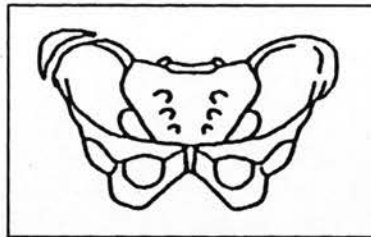
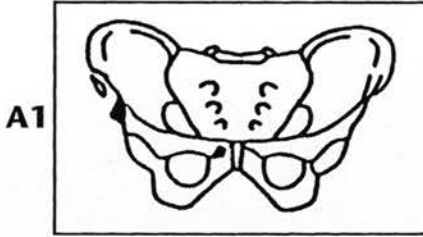
(1) anterior superior

(2) anterior inferior

(3) pubic spine

2. Iliac crest (61-A1.2)

3. Ischial tuberosity (61-A1.3)



Pelvis, ring, stable, innominate bone, direct blow (61-A2)

1. Iliac wing (61-A2.1)

(1) 1 fragment

(2) more than 1 fragment

2. Unilateral fracture of anterior arch (61-A2.2)

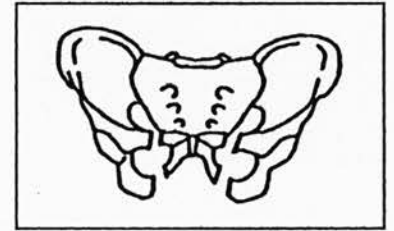
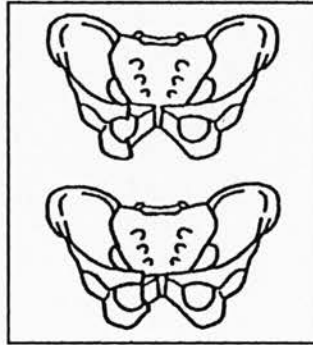
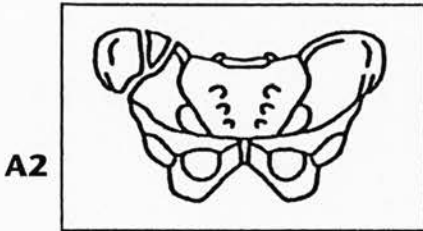
(1) through pubic bone/rami

(2) through pubic bone involving symphysis pubis

3. Bifocal fracture of anterior arch (61-A2.3)

(1) bilateral pubic rami

(2) pubic rami on 1 side and symphysis pubis

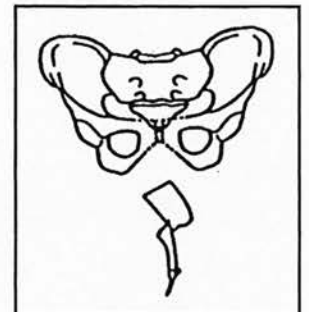
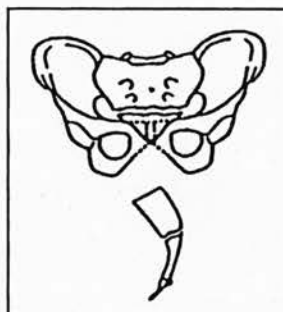
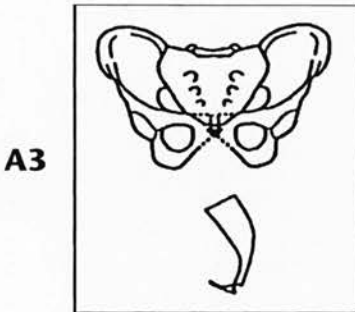


Pelvis, ring, stable, transverse fracture of sacrum and coccyx (61-A3)

1. Sacrococcygeal dislocation (61-A3.1)

2. Sacrum undisplaced (61-A3.2)

3. Sacrum displaced (61-A3.3)



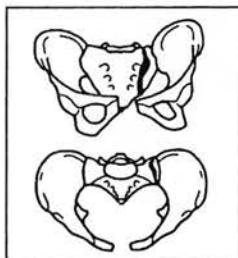
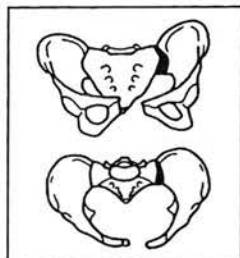
Pelvis, ring, partially stable, unilateral, external rotation (open book, APC-II) (61-B1)

- (1) ipsilateral
- (2) contralateral
- (3) anterior lesion

1. Sacroiliac joint anterior disruption (61-B1.1)

2. Sacral fracture (61-B1.2, c*)

B1



Pelvis, ring, partially stable, unilateral, internal rotation (lateral compression) (61-B2)

1. Anterior compression fracture of sacrum (LC-I) (61-B2.1)

- (1) anterior lesion ipsilateral
- (2) anterior lesion contralateral (bucket handle)

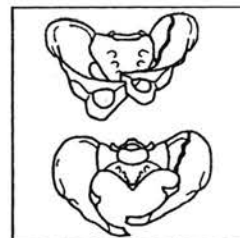
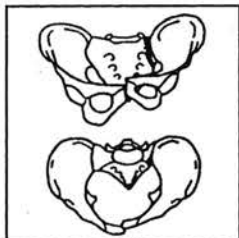
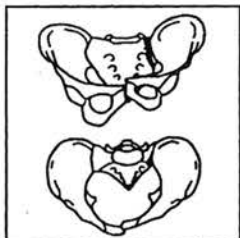
2. Partial sacroiliac joint fracture/subluxation (LC-II) (61-B2.2)

- (1) anterior lesion ipsilateral
- (2) anterior lesion contralateral (bucket handle)

3. Incomplete posterior iliac fracture (LC-II) (61-B2.3)

- (1) anterior lesion ipsilateral
- (2) anterior lesion contralateral (bucket handle)

B2



Pelvis, ring, partially stable, bilateral (61-B3)

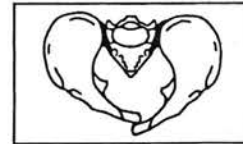
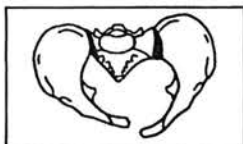
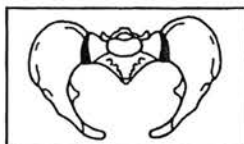
1. Bilateral B1 (open book, external rotation) (APC-II) (61-B3.1)

- (1) bilateral sacroiliac joint anterior disruption
- (2) bilateral sacral fracture
- (3) unilateral partial SI joint disruption/contralateral sacral fracture (c*)

2. B1 and B2 (LC-III) (61-B3.2, a*, b**, c*)

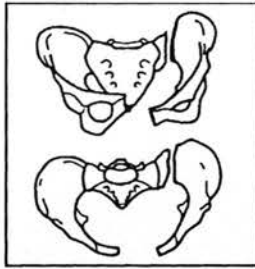
3. Bilateral B2 (61-B3.3, a*, b**, c*)

B3



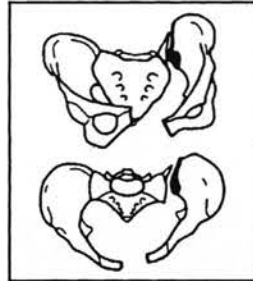
Pelvis, ring, complete disruption, unilateral (APC-III) (61-C1)

1. Through ilium (61-C1.1, c*)



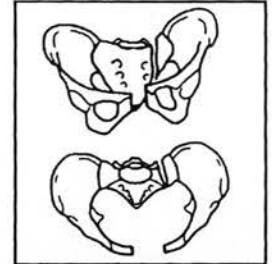
2. Through sacroiliac joint (61-C1.2, c*)

- (a¹) transiliac fracture dislocation
- (a²) pure dislocation
- (a³) transsacral fracture dislocation



3. Through the sacrum (61-C1.3, c*)

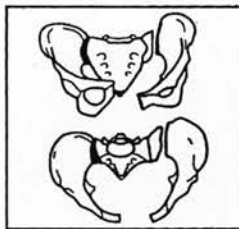
- (a¹) lateral (ala)
- (a²) foraminal
- (a³) medial to foramen



C1

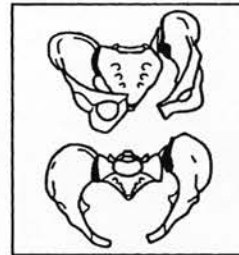
Pelvis, ring, unstable, bilateral, ipsilateral complete, contralateral incomplete (LC-III) (61-C2)

1. Complete through ilium (61-C2.1, b*, c*)



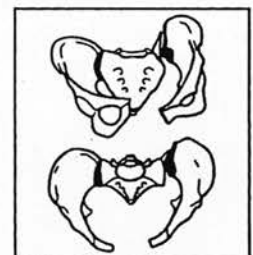
2. Complete through sacroiliac joint (61-C2.2, b*, c*)

- (a¹) transiliac fracture dislocation
- (a²) pure dislocation
- (a³) transsacral fracture dislocation



3. Complete through the sacrum (61-C2.3, b*, c*)

- (a¹) lateral (ala)
- (a²) foraminal
- (a³) medial to foramen

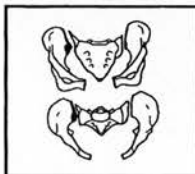


C2

Pelvis, ring, unstable, bilateral (APC-III) (61-C3, b***, c*)

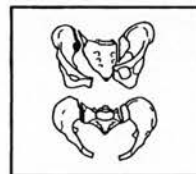
1. Extrasacral on both sides (61-C3.1)

- (a¹) ilium; (a²) SI joint, transiliac fracture/dislocation; (a³) SI joint, transsacral fracture/dislocation; (a⁴) SI joint dislocation



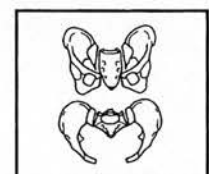
2. Sacral one side, extra sacral other side (61-C3.2, b***, c*)

- (a¹) sacral ala; (a²) sacral foraminal; (a³) sacral medial to foramen



3. Sacral both sides (61-C3.3, c*)

- (a) a¹) lateral alar; a²) foraminal; a³) medial
- (b) b¹) lateral alar; a²) foraminal; a³) medial



C3

Footnotes:

*a: Ipsilateral posterior pelvic lesion:

- a¹) sacroiliac joint anterior disruption; a²) sacral fracture; a³) anterior compression fracture sacrum; a⁴) partial sacroiliac joint fracture/subluxation; a⁵) incomplete posterior iliac fracture.

*b: Contralateral pelvic lesion:

- b¹) external rotation, "open book" partial disruption: .1) sacroiliac joint anterior disruption; .2) sacral fracture
- b²) internal rotation, "lateral compression" partial disruption: .1) anterior compression fracture of

the sacrum; .2) partial sacroiliac joint fracture/subluxation; .3) incomplete posterior iliac fracture

**b: Contralateral posterior pelvic lesion:

- b¹) sacroiliac joint anterior disruption; b²) sacral fracture; b³) anterior compression fracture sacrum; b⁴) partial sacroiliac joint fracture/subluxation; b⁵) incomplete posterior iliac fracture.

***b: Contralateral pelvic lesion:

- b¹) ilium; b²) sacroiliac joint, transiliac fracture dislocation; b³) sacroiliac joint, transsacral fracture dislocation; b⁴) sacroiliac joint, pure dislocation.

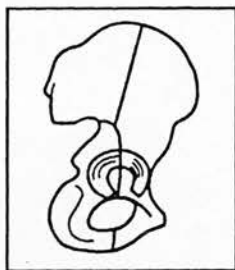
*c: Anterior pelvic lesion:

- c¹) unilateral pubis/rami fracture, ipsilateral; c²) unilateral pubis/rami fracture, contralateral; c³) bilateral pubis/rami fracture; c⁴) symphysis pubis disruption, pure < 2.5 cm; c⁵) symphysis pubis disruption, pure > 2.5 cm; c⁶) symphysis pubis disruption, pure, locked; c⁷) symphysis and ipsilateral pubis/rami fracture (tilt); c⁸) symphysis and contralateral pubis/rami fracture; c⁹) symphysis and bilateral pubis/rami fracture; c¹⁰) no anterior lesion.

BONE: PELVIS (6)

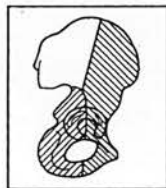
Modifiers to describe articular surfaces:
 α^1) femoral head subluxation, anterior; α^2) femoral head subluxation, medial; α^3) femoral head subluxation, posterior.
 ξ^1) femoral head dislocation, anterior; ξ^2) femoral head dislocation, medial; ξ^3) femoral head dislocation, posterior.
 χ^1) acetabular surface, chondral lesion; χ^2) acetabular surface, impacted.
 δ^1) femoral head, chondral lesion; δ^2) femoral head, impacted; δ^3) femoral head, osteochondral fracture.
 ϵ^1) intraarticular fragment requiring surgical removal.
 \varnothing^1) nondisplaced fracture of the acetabulum.

Location: Acetabulum (62)

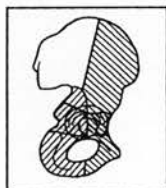


Types:

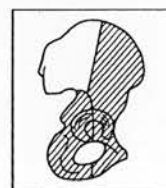
A. Partial articular, 1 column (62-A)



B. Partial articular, transverse (62-B)



C. Complete articular, both columns (62-C)



Groups:

Pelvis, acetabulum, partial articular, one column (62-A)

- 1. Posterior wall (62-A1)
- 2. Posterior column (62-A2)
- 3. Anterior (62-A3)

Pelvis, acetabulum, partial articular, transverse (62-B)

- 1. Transverse (62-B1)
- 2. T-shaped (62-B2)
- 3. Anterior column, posterior hemitransverse (62-B3)

Pelvis, acetabulum, complete articular, both columns (62-C)

- 1. High (62-C1)
- 2. Low (62-C2)
- 3. Involving sacroiliac joint (62-C3)

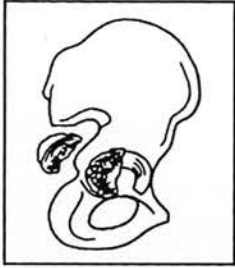


Subgroups and Qualifications:

Pelvis, acetabulum, partial articular, 1 column posterior wall (62-A1)

1. Pure fracture dislocation, 1 fragment (62-A1.1)

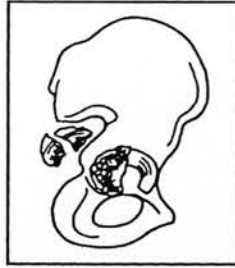
- (1) posterior
- (2) posterior superior
- (3) posterior inferior



A1

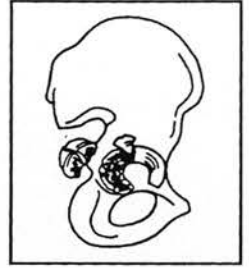
2. Pure fracture dislocation, multifragmentary (62-A1.2, a*)

- (1) posterior
- (2) posterior superior
- (3) posterior inferior



3. Fracture dislocation with marginal impaction (62-A1.3, a*)

- (1) posterior
- (2) posterior superior
- (3) posterior inferior



Pelvis, acetabulum, partial articular, 1 column posterior column (62-A2)

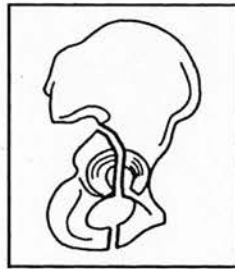
1. Through ischium (62-A2.1)



A2

2. Through obturator ring (62-A2.2)

- (1) preserving tear drop
- (2) involving tear drop



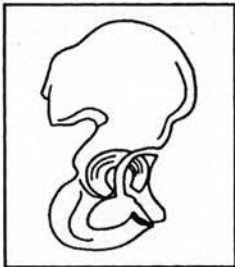
3. Associated with posterior wall (62-A2.3, a*)

- (1) pure fracture dislocation: .1) posterior; .2) posterior superior; .3) posterior inferior
- (2) with marginal impaction: .1) posterior; .2) posterior superior; .3) posterior inferior



Pelvis, acetabulum, partial articular, one column anterior (62-A3, a**)

1. Anterior wall (62-A3.1)

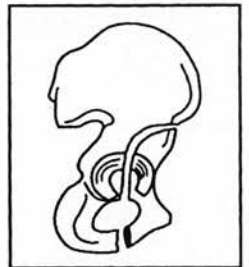


A3

2. Anterior column, high (fracture to iliac crest) (62-A3.2)



3. Low (fracture to anterior border of iliac crest) (62-A3.3)

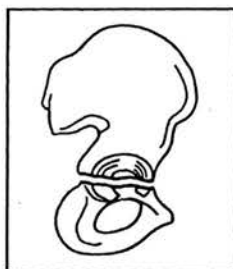


*a: a¹) 1 fragment; a²) 2 fragments; a³) more than 2 fragments.

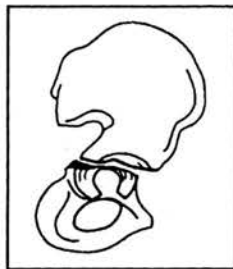
**a: a¹) anterior column in 1 fragment; a²) anterior column in 2 fragments; a³) anterior column in more than 2 fragments.

Pelvis, acetabulum, partial articular, transverse (62-B1)

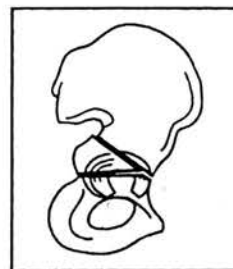
1. Infratectal (62-B1.1, a*)



2. Juxtatectal (62-B1.2, a*)



3. Transtectal (62-B1.3, a*)

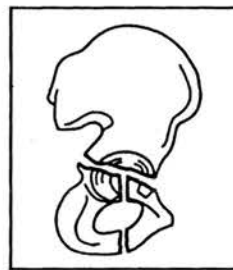


B1

Pelvis, acetabulum, partial articular, transverse T-type (62-B2)

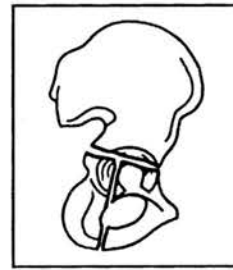
1. Infratectal (62-B2.1, a*)

- (1) stem posterior
- (2) stem through obturator foramen
- (3) stem anterior



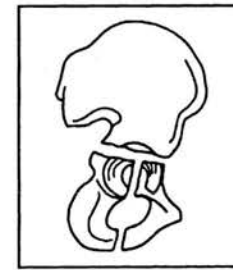
2. Juxtatectal (62-B2.2, a*)

- (1) stem posterior
- (2) stem through obturator foramen
- (3) stem anterior



3. Transtectal (62-B2.3, a*)

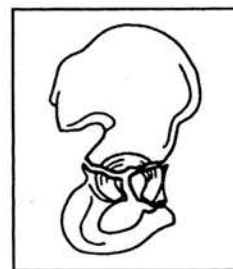
- (1) stem posterior
- (2) stem through obturator foramen
- (3) stem anterior



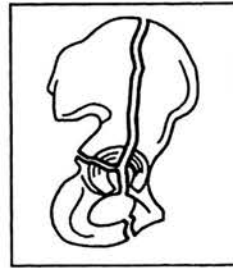
B2

Pelvis, acetabulum, partial articular, transverse posterior hemitransverse, anterior column (62-B3)

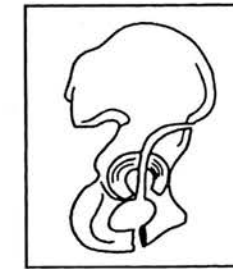
1. Anterior wall (62-B3.1)



2. Anterior column high (62-B3.2, a**)



3. Anterior column low (62-B3.3, a**)



B3

*a: a¹) pure transverse; a²) and posterior wall, single fragments; a³) and posterior wall, multifragmentary; a⁴) and posterior wall, multifragmentary with marginal impaction.

**a: a¹) anterior column in 1 fragment; a²) anterior column in 2 fragments; a³) anterior column in more than 2 fragments.

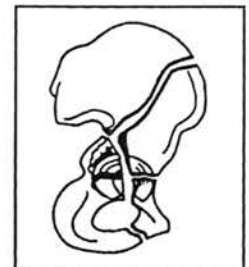
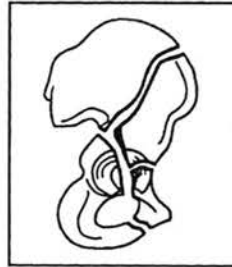
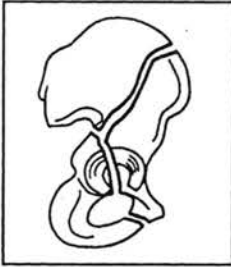
Pelvis, acetabulum, complete, both columns high (62-C1)

1. Each column simple (62-C1.1)

2. Posterior column simple, anterior column multifragmentary (62-C1.2)

3. Posterior column and posterior wall (62-C1.3, a**, b*)

C1



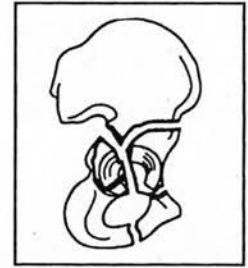
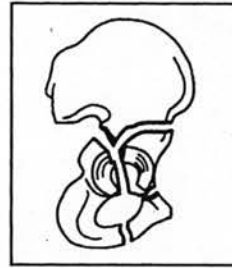
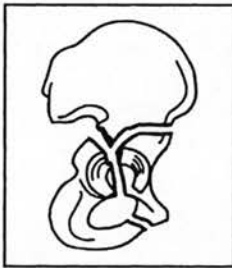
Pelvis, acetabulum, complete articular, both columns low (62-C2)

1. Each column simple (62-C2.1)

2. Posterior column simple, anterior column multifragmentary (62-C2.2)

3. Posterior column and posterior wall (62-C2.3, a**, b*)

C2



Pelvis, acetabulum, complete articular, both columns involving sacroiliac joint (62-C3)

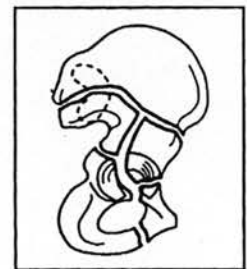
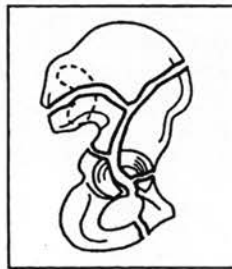
1. Anterior wall (62-C3.1)

(a¹) anterior column simple, high
(a²) anterior column simple, low
(a³) anterior column multifragmentary, high
(a⁴) anterior column multifragmentary, low

2. Posterior column multifragmentary, anterior column high (62-C3.2, a***, b**)

3. Posterior column multifragmentary, anterior column low (62-C3.3, a***, b**)

C3



**a: a¹) anterior column in 1 fragment; a²) anterior column in 2 fragments; a³) anterior column in more than 2 fragments.

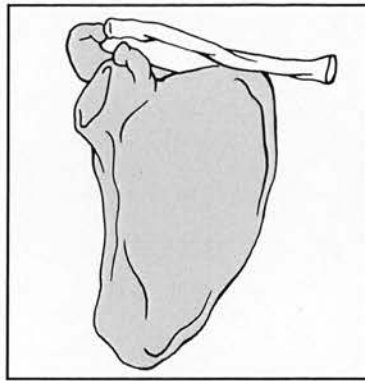
***a: a¹) anterior column simple; a²) anterior column multifragmentary.

**b: b¹) posterior wall, single fragment; b²) posterior wall, multifragmentary without impaction; b³) posterior wall, multifragmentary with marginal impaction.

**b: b¹) pure separation; b²) and posterior wall, single fragment; b³) and posterior wall, multifragmentary without impaction; b⁴) and posterior wall, multifragmentary with marginal impaction.

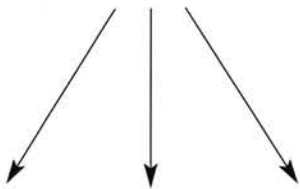
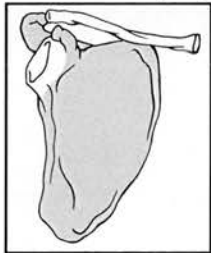
SCAPULA

BONE: SCAPULA (14)

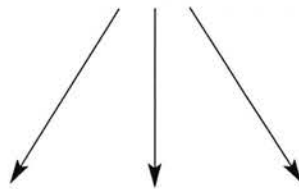
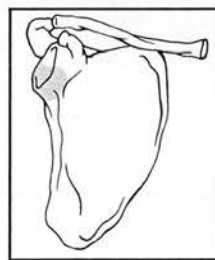


Types:

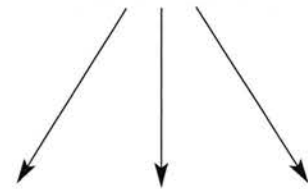
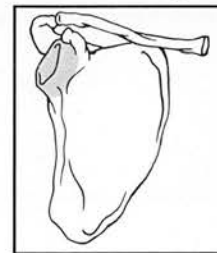
A. Extra-articular (not glenoid) (14-A)



B. Partial articular (glenoid) (14-B)



C. Total articular (glenoid) (14-C)



Groups:

Scapula, extra-articular (not glenoid) (14-A)
 1. Acromion (14-A1) 2. Coracoid (14-A2) 3. Body (14-A3)

Scapula, partial articular (glenoid) (14-B)
 1. Anterior rim (14-B1) 2. Posterior rim (14-B2) 3. Inferior rim (14-B3)

Scapula, total articular (glenoid) (14-C)
 1. Extra-articular glenoid neck (14-C1) 2. Intra-articular with neck (14-C2) 3. Intra-articular with body (14-C3)

Subgroups:

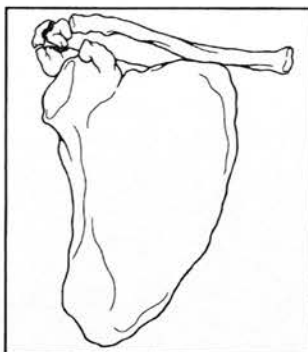
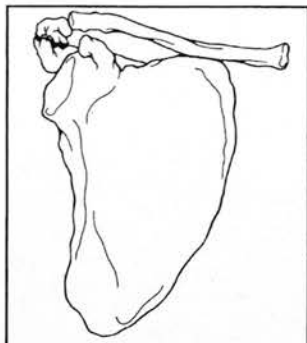
Scapula extra-articular (not glenoid) (14-A)

Acromion (14-A1)

1. Acromion, noncomminuted (14-A1.1)

2. Acromion, comminuted (14-A1.2)

A1

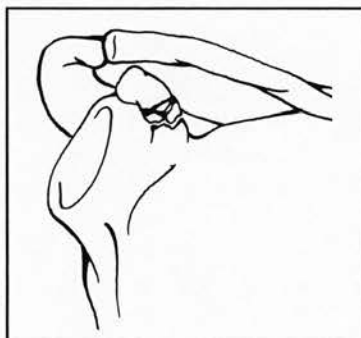
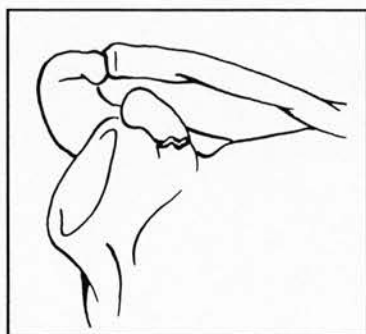


Coracoid (14-A2)

1. Coracoid, noncomminuted (14-A2.1)

2. Coracoid, comminuted (14-A2.2)

A2

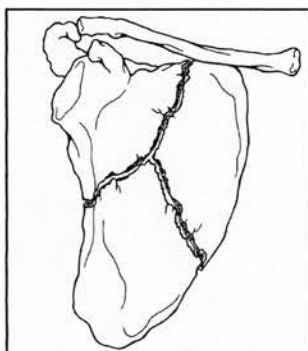
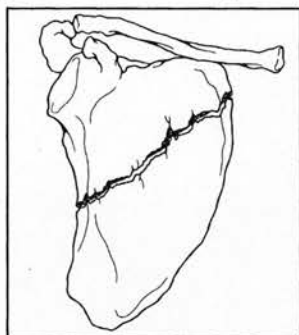


Body (14-A3)

1. Body, noncomminuted (14-A3.1)

2. Body, comminuted (14-A3.2)

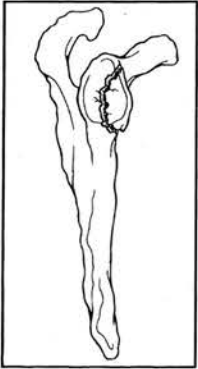
A3



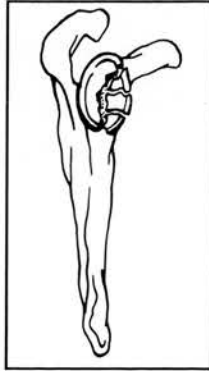
Subgroups:
Scapula extra-articular (glenoid) (14-B)

Anterior rim (14-B1)

1. Anterior rim, noncomminuted (14-B1.1)



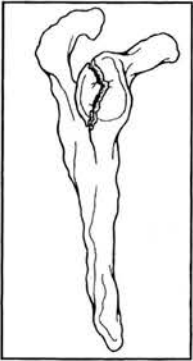
2. Anterior rim, comminuted (14-B1.2)



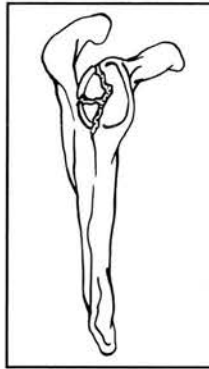
B1

Posterior rim (14-B2)

1. Posterior rim, noncomminuted (14-B2.1)



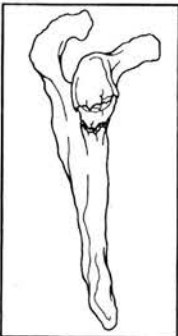
2. Posterior rim, comminuted (14-B2.2)



B2

Inferior rim (14-B3)

1. Inferior rim, noncomminuted (14-B3.1)



2. Inferior rim, comminuted (14-B3.2)

B3

Subgroups:

Scapula extra-articular (glenoid) (14-C)

Extra-articular glenoid neck (14-C1)

1. Extra-articular glenoid neck, noncomminuted (14-C1.1)

2. Extra-articular glenoid neck, comminuted (14-C1.2)

C1



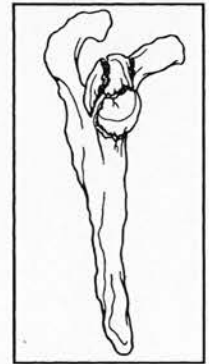
Intra-articular with neck (14-C2)

1. Intra-articular with neck, articular noncomminuted, neck noncomminuted (14-C2.1)

2. Intra-articular with neck, comminuted, articular noncomminuted (14-C2.2)

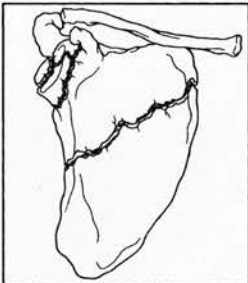
3. Intra-articular with glenoid neck, articular comminuted (14-C2.3)

C2



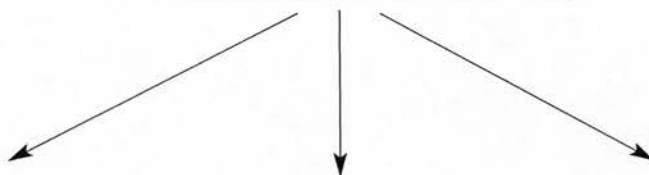
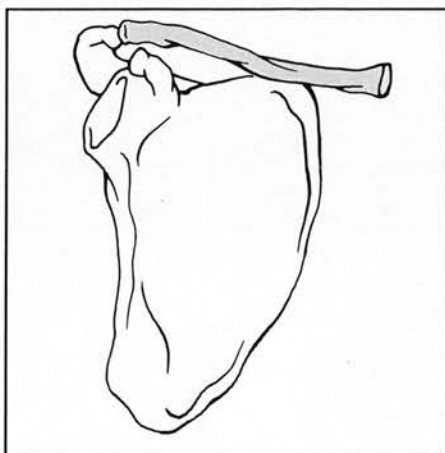
Intra-articular with body (14-C3)

C3



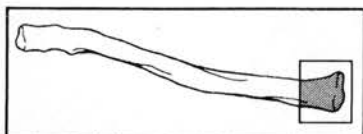
CLAVICLE

BONE: CLAVICLE (15)

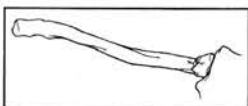


Location: Medial end (15-A)

Type:
A. Clavicle, medial end (15-A)



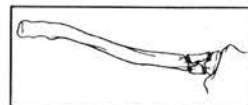
Group:
Clavicle, medial end (15-A)
1. Extra-articular (15-A1)



2. Intra-articular (15-A2)

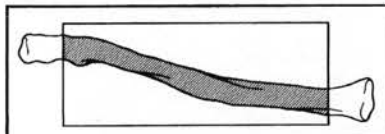


3. Comminuted (15-A3)

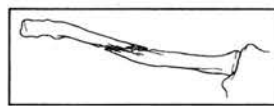


Location: Diaphysis (15-B)

Type:
B. Clavicle, diaphysis (15-B)



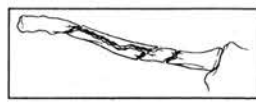
Clavicle, diaphysis (15-B)
1. Simple (15-B1)



2. Wedge (15-B2)

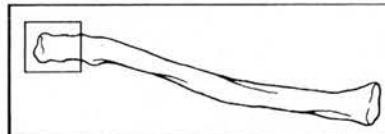


3. Complex (15-B3)

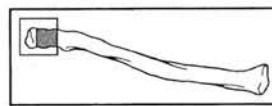


Location: Lateral end (15-C)

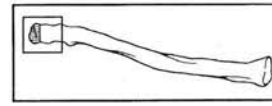
Type:
C. Clavicle, lateral end (15-C)



Clavicle, lateral end (15-C)
1. Extra-articular (15-C1)



2. Intra-articular (15-C2)

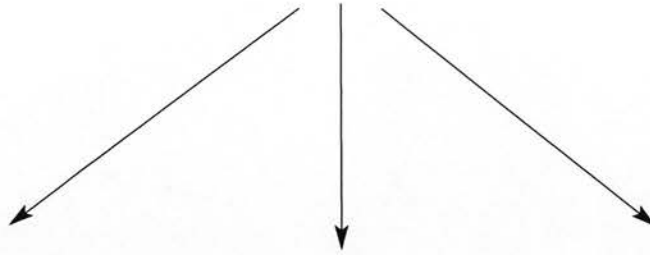
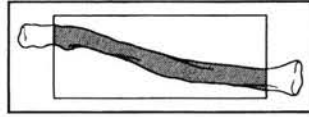


Note for clavicle:

- There are no subgroups of A.

BONE: CLAVICLE

Location: Diaphysis (15-B)



Groups:

Clavicle, diaphysis, noncomminuted (15-B1)

Subgroups:

1. Spiral (15-B1.1)



2. Oblique (15-B1.2)



3. Transverse (15-B1.3)



Clavicle, diaphysis, wedge (15-B2)

1. Spiral wedge (15-B2.1)



2. Bending wedge (15-B2.2)



3. Comminuted (15-B2.3)



Clavicle, diaphysis, segmental (15-B3)

1. Spiral (15-B3.1)



2. 2 transverse (15-B3.2)

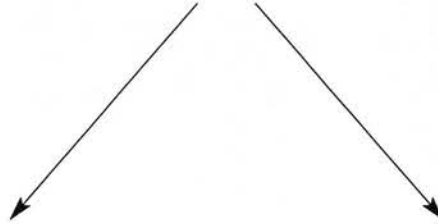
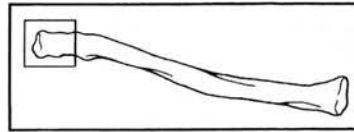


3. Complex comminuted (15-B3.3)



BONE: CLAVICLE

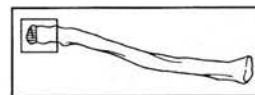
Location: Lateral end (15-C)



Groups:
Clavicle, lateral end, extra-articular
(15-C1)



Clavicle, lateral end, intra-articular
(15-C2)



Subgroups:
1. Impacted (C-C ligament intact)
(15-C1.1)



1. With slight displacement (C-C ligament intact) (15-C2.1)



2. Noncomminuted (C-C ligament disrupted) (15-C1.2)



2. Noncomminuted (C-C ligament disrupted) (15-C2.2)



3. Comminuted (C-C ligament disrupted) (15-C1.3)

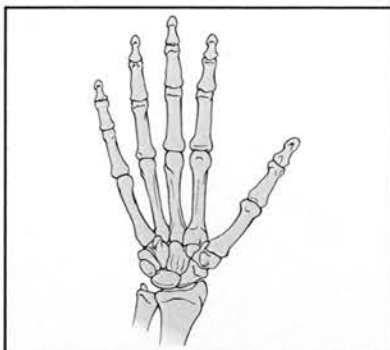


3. Comminuted (C-C ligament disrupted) (15-C2.3)



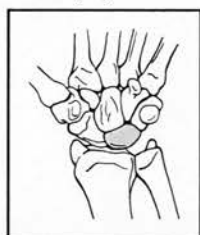
HAND AND CARPUS

AREA: HAND AND CARPUS (71-79)

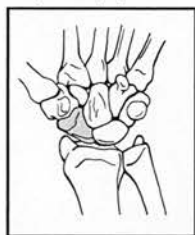


Bones:

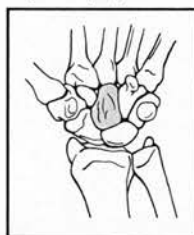
Lunate (71)



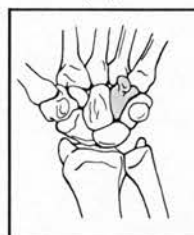
Scaphoid (72)



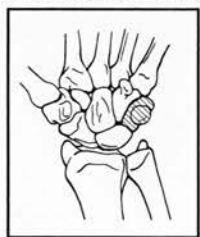
Capitate (73)



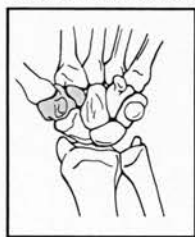
Hamate (74)



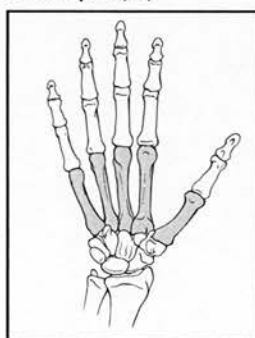
Ulnar carpal bones (75)



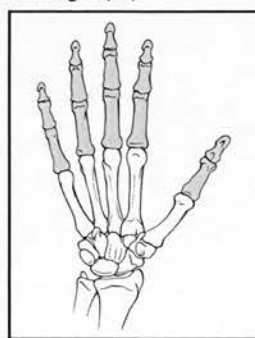
Radial carpal bones (76)



Metacarpals (77)



Phalanges (78)



Multiple hand and carpal fractures (79)

A. Carpal (79-A)

B. Metacarpal (79-B)

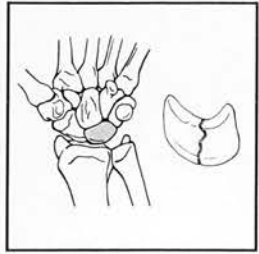
C. Phalanges (79-C)

Location: Carpus (71-76)

Types:

- A. Noncomminuted
- B. Comminuted

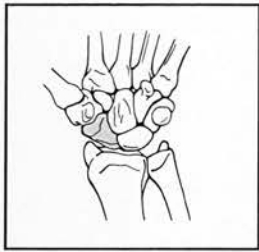
Lunate (71)



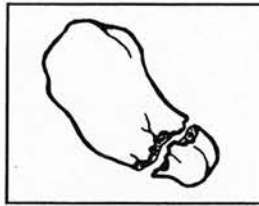
A. Noncomminuted (71-A)

B. Comminuted (71-B)

Scaphoid (72)

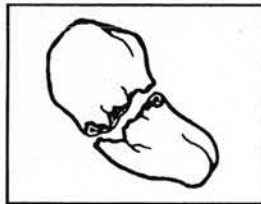


A. Noncomminuted (72-A)
 1. Proximal Pole (72-A1)

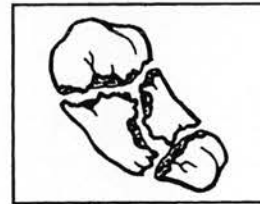


B. Comminuted (72-B)
 1. Proximal Pole (72-B1)

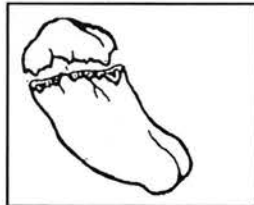
2. Waist (72-A2)



2. Waist (72-B2)

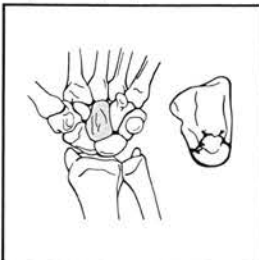


3. Distal pole (72-A3)



3. Distal Pole (72-B3)

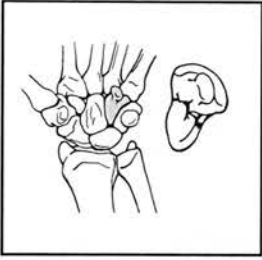
Capitate (73)



A. Noncomminuted (73-A)

B. Comminuted (73-B)

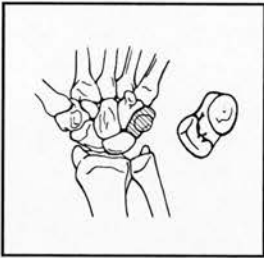
Hamate (74)



A. Noncomminuted (74-A)

B. Comminuted (74-B)

Ulnar carpal bones (75)



A. Noncomminuted (75-A)

B. Comminuted (75-B)

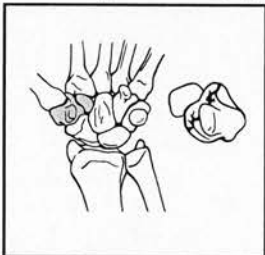
1. Pisiform (75-A1)

1. Pisiform (75-B1)

2. Triquetrum (75-A2)

2. Triquetrum (75-B2)

Radial carpal bones (76)



A. Noncomminuted (76-A)

B. Comminuted (76-B)

1. Trapezium (76-A1)

1. Trapezium (76-B1)

2. Trapezoid (76-A2)

2. Trapezoid (76-B2)

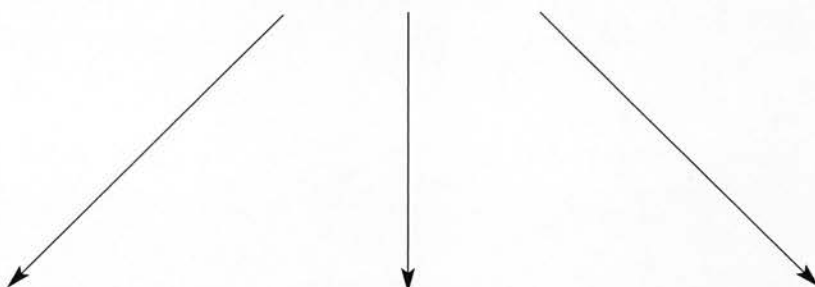
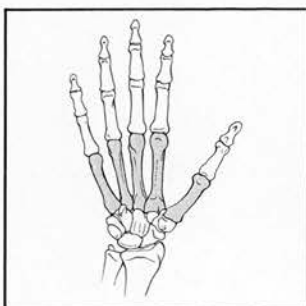
METACARPALS

BONE: METACARPALS (77)

Modifiers for metacarpals:

T, thumb; I, index; M, middle; R, ring; L, little.

Location: Metacarpals (77)

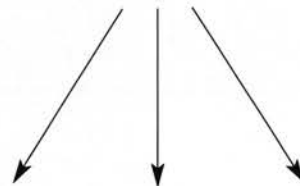
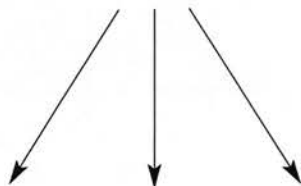
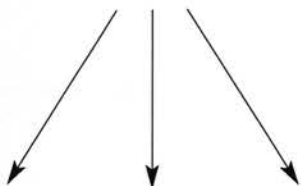


Types:

A. Metacarpal proximal and distal nonarticular and diaphysis non-comminuted (77-A)

B. Metacarpal proximal and distal partial articular diaphysis wedge comminution (77-B)

C. Metacarpal proximal and distal complete articular diaphysis comminuted (77-C)



Groups:

1. Metacarpal, proximal extra-articular (77-A1)

2. Metacarpal, diaphysis non-comminuted (77-A2)

3. Metacarpal, distal extra-articular (77-A3)

1. Metacarpal, proximal partial articular (77-B1)

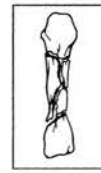
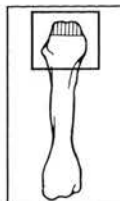
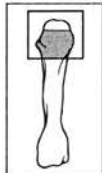
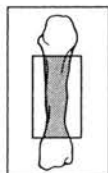
2. Metacarpal, diaphysis wedge (77-B2)

3. Metacarpal, distal partial articular (77-B3)

1. Metacarpal, proximal complete articular (77-C1)

2. Metacarpal, diaphysis comminuted (77-C2)

3. Metacarpal, distal complete articular (77-C3)



Subgroups and Qualifications:

Metacarpal, proximal extra-articular (77-A1)

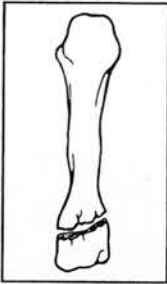
1. Noncomminuted (77-A1.1)

2. Comminuted (77-A1.2)

(1) wedge

(2) complex

A1



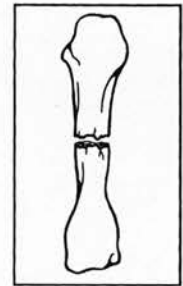
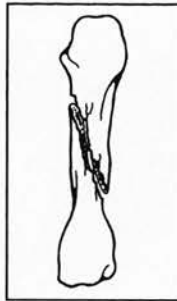
Metacarpal, diaphysis noncomminuted (77-A2)

1. Spiral (77-A2.1)

2. Oblique (77-A2.2)

3. Transverse (77-A2.3)

A2



Metacarpal, distal extra-articular (77-A3)

1. Noncomminuted (77-A3.1)

2. Comminuted (77-A3.2)

A3



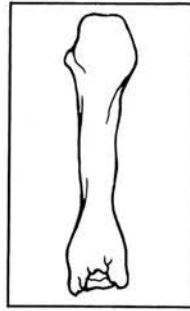
Metacarpal, proximal partial articular (77-B1)

1. Avulsion OR Split (77-B1.1)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

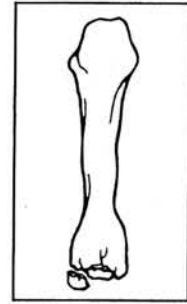


2. Depression (77-B1.2)



3. Split/depression (77-B1.3)

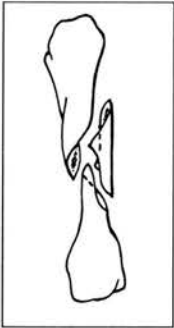
- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment



B1

Metacarpal, diaphysis wedge (77-B2)

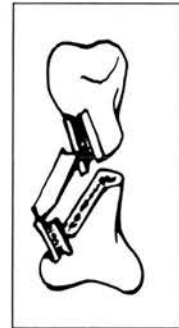
1. Spiral (77-B2.1)



2. Bending (77-B2.2)



3. Comminuted (77-B2.3)

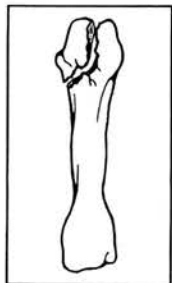


B2

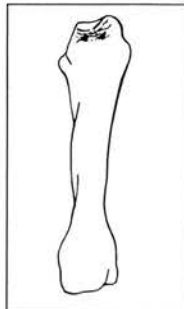
Metacarpal, distal partial articular (77-B3)

1. Avulsion OR Split (77-B3.1)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

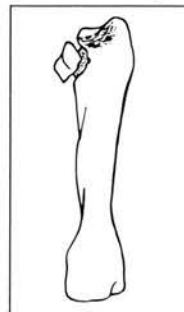


2. Depression (77-B3.2)



3. Split/depression (77-B3.3)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

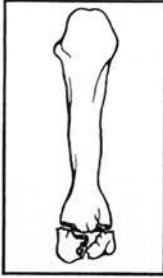


B3

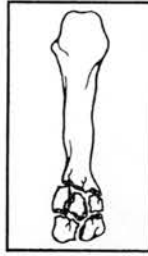
Metacarpal, proximal articular (77-C1)

1. Noncomminuted articular and metaphysis (77-C1.1)

C1



2. Noncomminuted articular, comminuted metaphysis (77-C1.2)



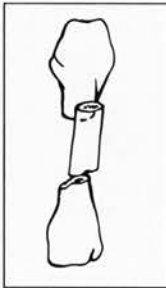
3. Comminuted articular (77-C1.3)



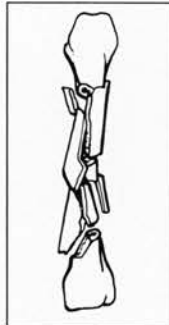
Metacarpal, diaphysis comminuted (77-C2)

1. Segmental (77-C2.1)

C2



2. Complex comminuted (77-C2.2)



Metacarpal, distal articular (77-C3)

1. Simple articular/metaphysis (77-C3.1)

C3



2. Simple articular/comminuted metaphysis (77-C3.2)



3. Comminuted articular (77-C3.3)

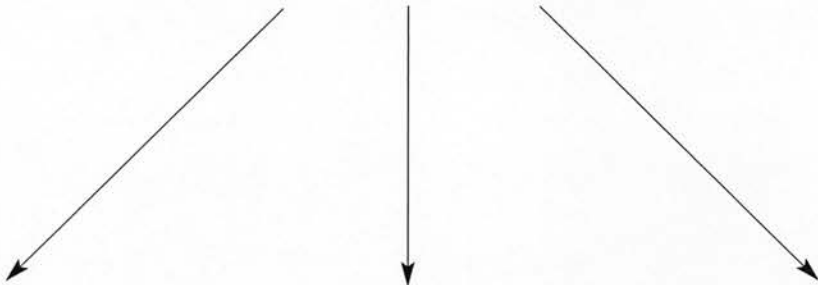
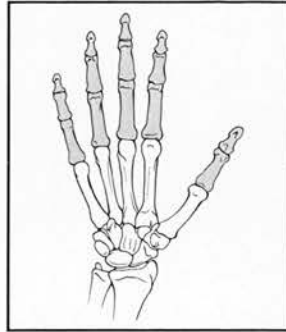


PHALANX - HAND

BONE: PHALANX (78)

Modifiers for phalanx:
 T1 and T2, thumb 1/2;
 N1, N2 and N3, index
 1/2/3; M1, M2 and M3,
 middle 1/2/3; R1, R2
 and R3, ring 1/2/3; L1,
 L2 and L3, little 1/2/3.

Location: Phalanx (78)

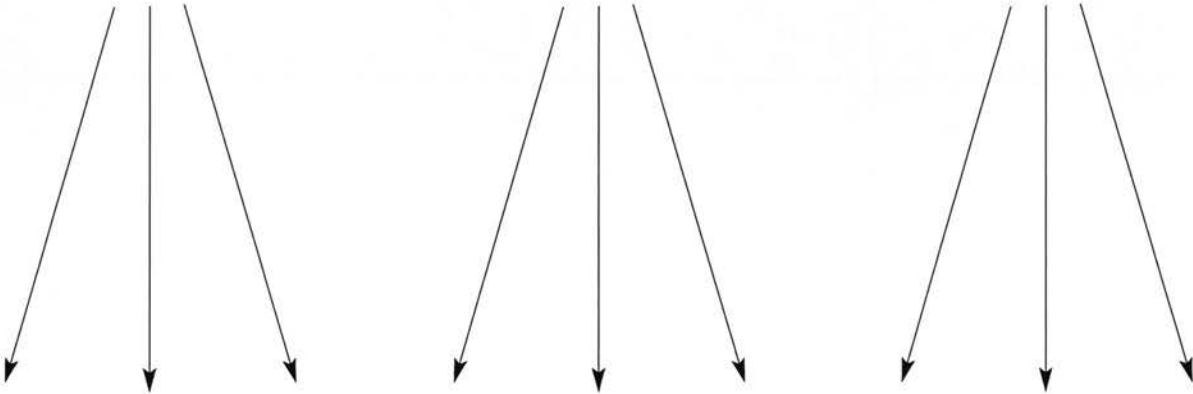


Types:

A. Phalanx proximal and distal extra-articular and diaphysis noncomminuted (78-A)

B. Phalanx proximal and distal partial articular and diaphysis wedge comminution (78-B)

C. Phalanx proximal and distal complete articular and diaphysis comminuted (78-C)



Groups:

1. Phalanx, proximal extra-articular (78-A1)

2. Phalanx diaphysis, non-comminuted (78-A2)

3. Phalanx, distal extra-articular (78-A3)

1. Phalanx, proximal partial articular (78-B1)

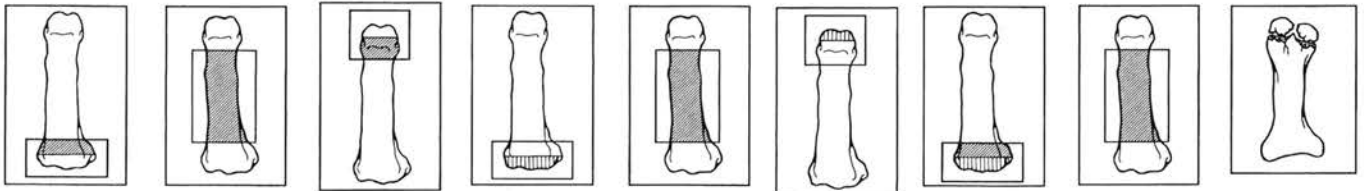
2. Phalanx, diaphysis wedge (78-B2)

3. Phalanx, distal partial articular (78-B3)

1. Phalanx, proximal complete articular (78-C1)

2. Phalanx, diaphysis comminuted (78-C2)

3. Phalanx, distal complete articular (78-C3)



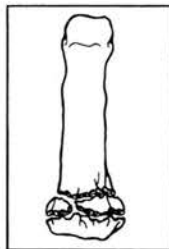
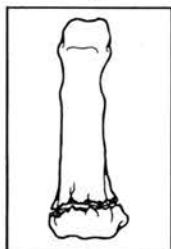
Subgroups and Qualifications:

Phalanx, proximal extra-articular (78-A1)

1. Noncomminuted (78-A1.1)

2. Comminuted (78-A1.2)

A1



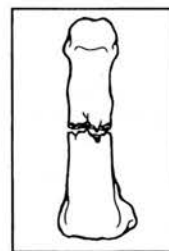
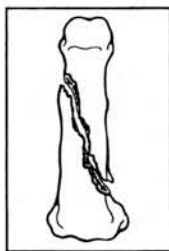
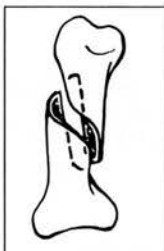
Phalanx diaphyseal noncomminuted (78-A2)

1. Spiral (78-A2.1)

2. Oblique (78-A2.2)

3. Transverse (78-A2.3)

A2

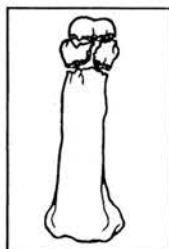
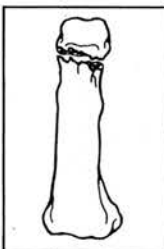


Phalanx, distal extra-articular (78-A3)

1. Spiral noncomminuted (78-A3.1)

2. Comminuted (78-A3.2)

A3

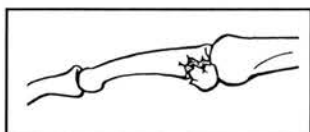
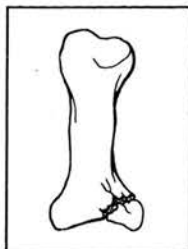


Phalanx, proximal partial articular (78-B1)

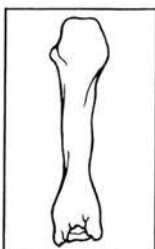
1. Avulsion OR Split (78-B1.1)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

B1

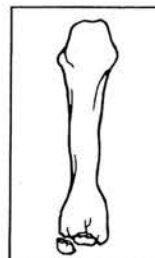


2. Depression (78-B1.2)



3. Split/depression (78-B1.3)

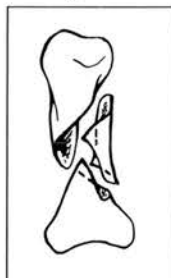
- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment



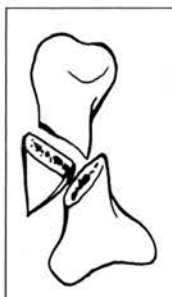
Phalanx, diaphysis wedge (78-B2)

1. Spiral (78-B2.1)

B2



2. Bending (78-B2.2)



3. Fragmented (78-B2.3)

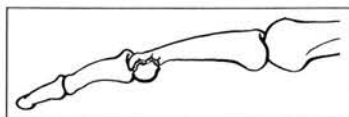
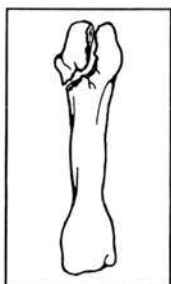


Phalanx, distal partial articular (78-B3)

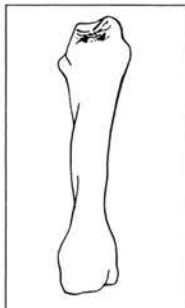
1. Avulsion OR Split (78-B3.1)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

B3

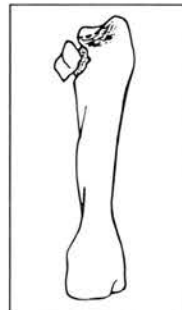


2. Depression (78-B3.2)



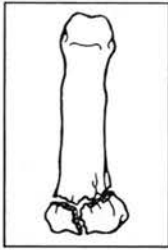
3. Split/depression (78-B3.3)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

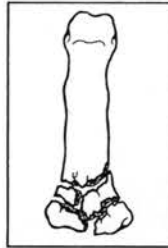


Phalanx, proximal complete articular (78-C1)

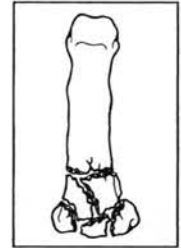
1. Noncomminuted articular/metaphysis (78-C1.1)



2. Noncomminuted articular/comminuted metaphysis (78-C1.2)



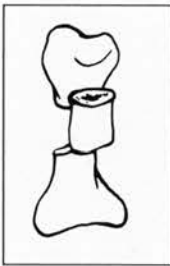
3. Comminuted articular and metaphysis (78-C1.3)



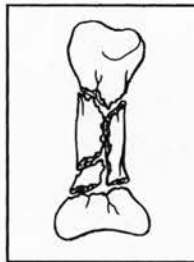
C1

Phalanx, diaphysis comminuted (78-C2)

1. Segmental (78-C2.1)



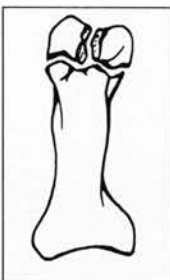
2. Complex comminuted (78-C2.2)



C2

Phalanx, distal articular (78-C3)

1. Noncomminuted articular/metaphysis (78-C3.1)



2. Noncomminuted articular/comminuted metaphysis (78-C3.2)



3. Comminuted articular (78-C3.3)

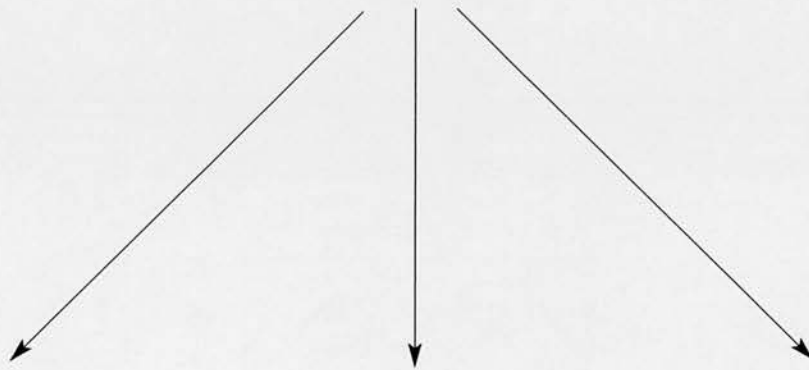


C3

PATELLA

BONE: PATELLA (34)

Location: Patella (34)

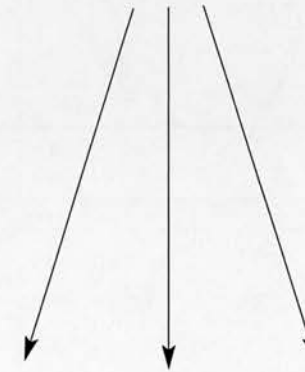
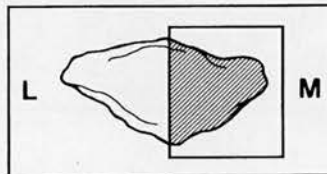
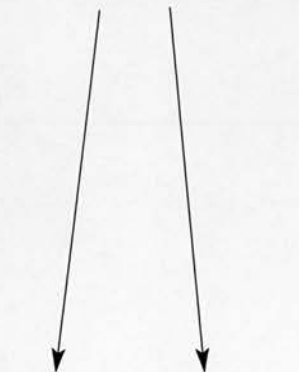
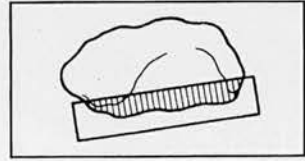
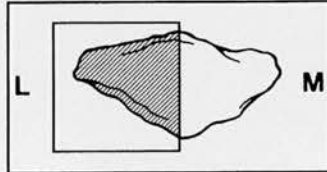
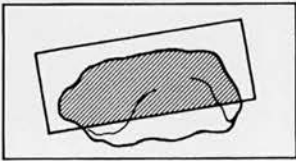


Types:

A. Patella extra-articular (34-A)

B. Partial articular, vertical (34-B)

C. Complete articular, non-vertical (34-C)

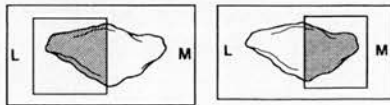
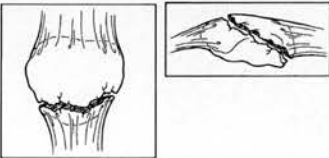


Groups:

- Patella, extra-articular (34-A)
1. Patella, extra-articular, avulsion (34-A1)
 2. Patella, extra-articular isolated body (34-A2)

- Patella, partial articular, vertical (34-B)
1. Patella, partial articular, vertical, lateral (34-B1)
 2. Patella, partial articular, vertical, medial (34-B2)

- Patella, complete articular, non-vertical (34-C)
1. Patella, articular, transverse (34-C1)
 2. Patella, articular, transverse plus second fragment (34-C2)
 3. Patella, articular, comminuted (34-C3)



Note for patella:

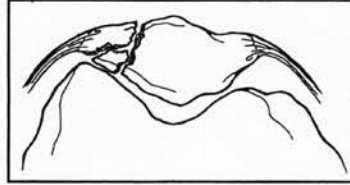
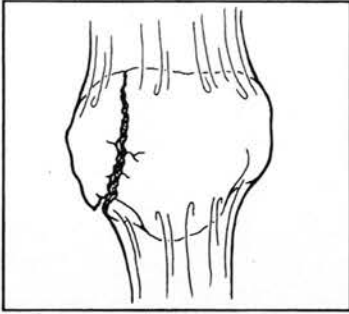
- There are no subgroups of A.

Patella, partial articular, vertical, lateral (34-B1)

1. Noncomminuted (34-B1.1)

2. Comminuted (34-B1.2)

B1

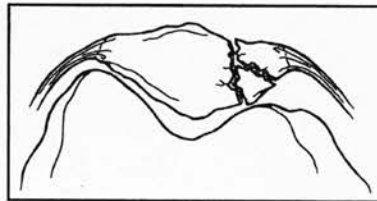
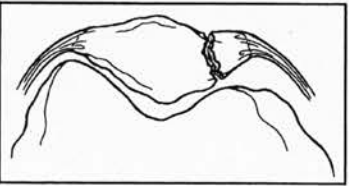
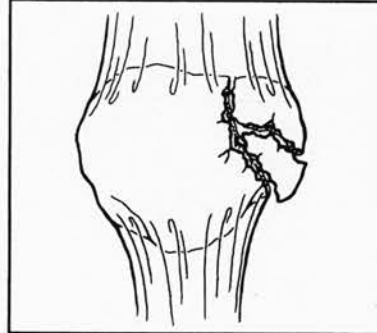
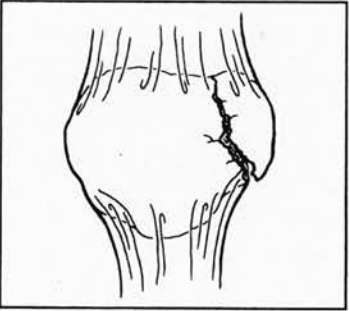


Patella, partial articular, vertical, medial (34-B2)

1. Noncomminuted (34-B2.1)

2. Comminuted (34-B2.2)

B2



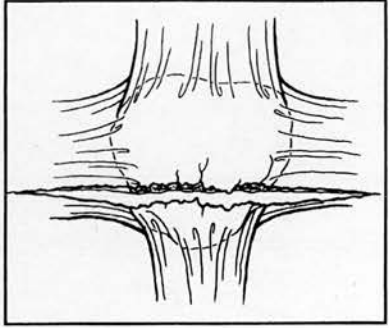
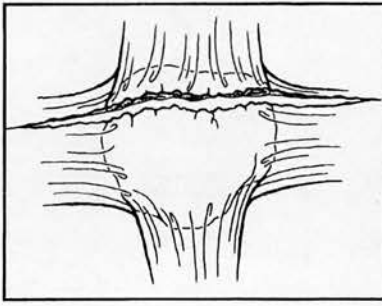
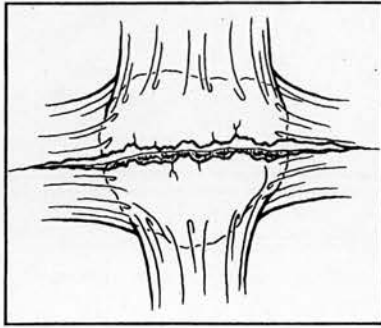
Patella, complete articular, transverse (34-C1)

1. Middle (34-C1.1)

2. Proximal (34-C1.2)

3. Distal (34-C1.3)

C1



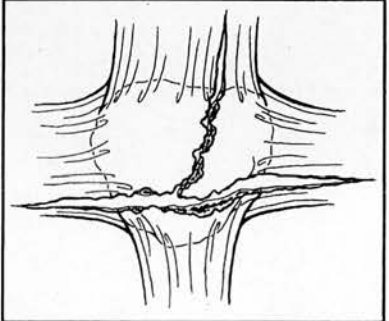
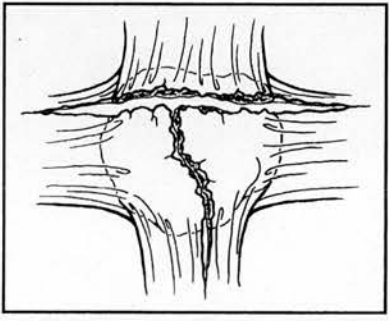
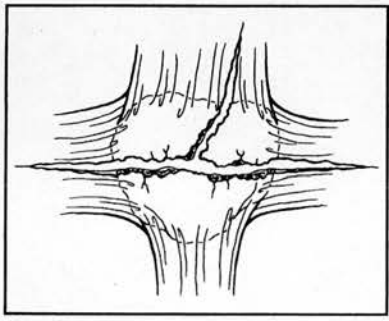
Patella, articular, transverse plus second fragment (34-C2)

1. Middle (34-C2.1)

2. Proximal (34-C2.2)

3. Distal (34-C2.3)

C2

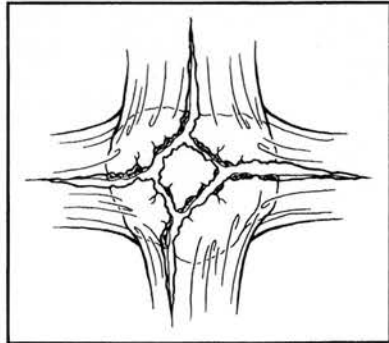
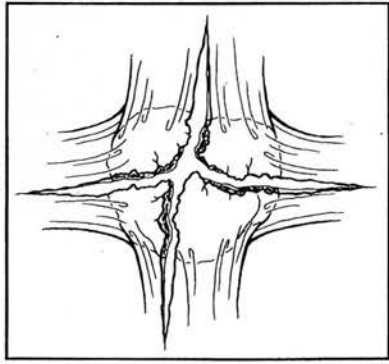


Patella, articular, complex (34-C3)

1. With 3 fragments (34-C3.1)

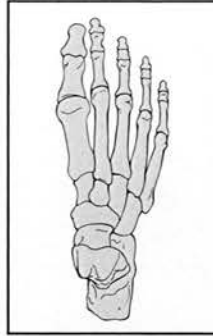
2. More than 3 fragments (34-C3.2)

C3



FOOT

AREA: FOOT (81-89)



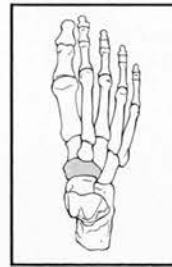
Bones:
Talus (81)



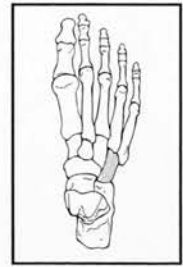
Calcaneus (82)



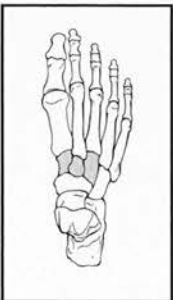
Navicular (83)



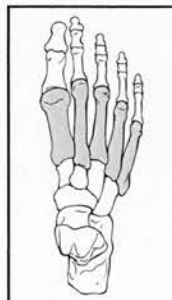
Cuboid (84)



Cuneiforms (85)



Metatarsals (87)



Phalanges (88)



Crush, multiple foot fractures (89)

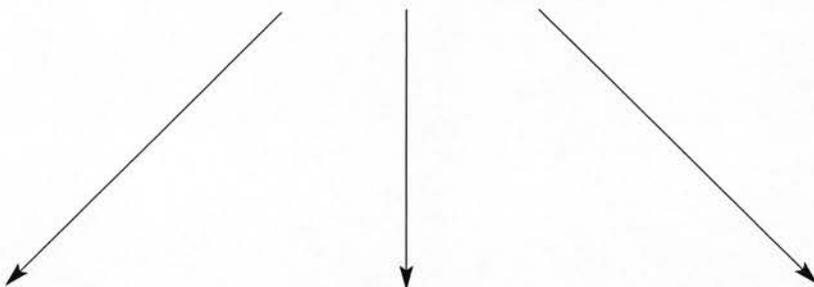
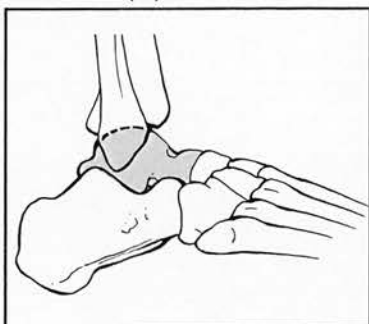
- A. Hind Foot (89-A)
- B. Midfoot (89-B)
- C. Forefoot (89-C)

Note for foot:

- To stay as consistent with hand as possible, there are no bones coded for 86 allowing metacarpals and metatarsals and hand and foot phalanges each to be coded with the same last digit.

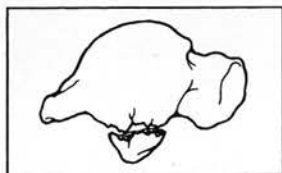
Location: Foot (81-85)

BONE: TALUS (81)

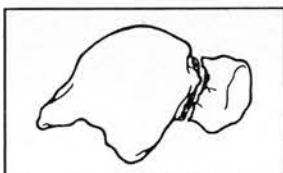


Types:

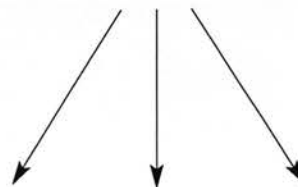
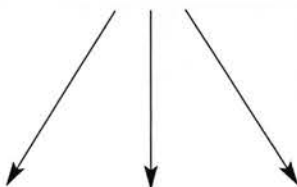
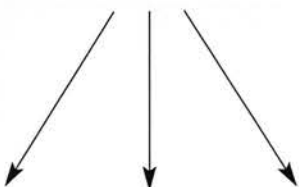
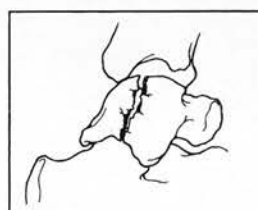
A. Avulsion or process or head fractures (81-A)



B. Neck fractures (81-B)



C. Body fractures (81-C)



Groups:

Talus avulsions process, or head fractures (81-A)

- 1. Avulsions (81-A1)
- 2. Process (81-A2)
- 3. Head fractures (without neck fracture) (81-A3)

Neck fractures (81-B)

- 1. Nondisplaced (81-B1)
- 2. Displaced with subluxation of subtalar joint (81-B2)
- 3. Displaced with subluxation of subtalar and ankle joints (81-B3)

Body fractures (81-C)

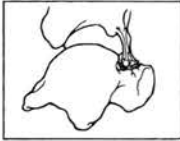
- 1. Ankle joint involvement, dome fractures (81-C1)
- 2. Subtalar joint involvement (81-C2)
- 3. Ankle and subtalar joint involvement (81-C3)

Groups:

Talus avulsions, process or head fractures (81-A)

1. Avulsions (81-A1)
1. Anterior (81-A1.1)

A



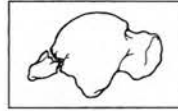
2. Other (81-A1.2)

2. Process (81-A2)

1. Lateral (81-A2.1)

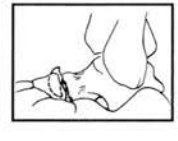
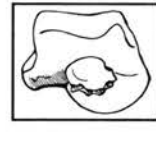


2. Posterior (81-A2.2)

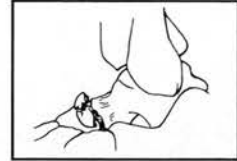


3. Head fractures (without neck fracture) (81-A3)

1. Noncomminuted (81-A3.1)



2. Comminuted (81-A3.2)

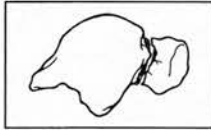


Groups:

Neck fractures (81-B)

1. Nondisplaced (81-B1)

B



2. Displaced with subluxation of subtalar joint (81-B2)

1. Noncomminuted (81-B2.1)



2. Comminuted (81-B2.2)



3. Involves talar head (81-B2.3)

3. Displaced with subluxation of subtalar and ankle joints (81-B3)

1. Noncomminuted (81-B3.1)



2. Comminuted (81-B3.2)



3. Involves talar head (81-B3.3)

Groups:

Body fractures (81-C)

1. Ankle joint involvement, dome fractures (81-C1)

1. Noncomminuted (81-C1.1)

C



2. Comminuted (81-C1.2)



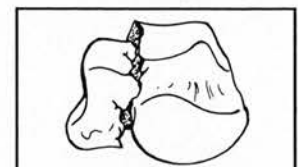
2. Subtalar joint involvement (81-C2)

1. Noncomminuted (81-C2.1)

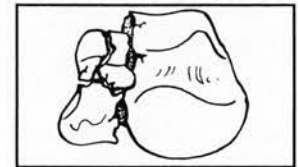
2. Comminuted (81-C2.2)

3. Ankle and subtalar joint involvement (81-C3)

1. Noncomminuted (81-C3.1)

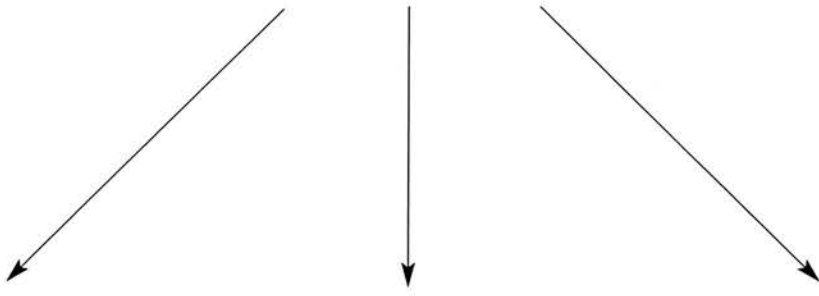
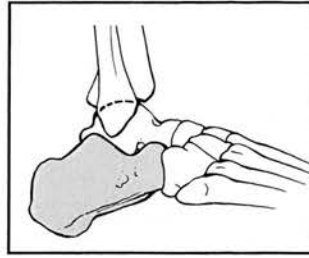


2. Comminuted (81-C3.2)



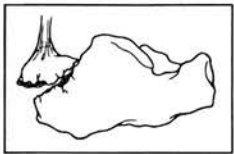
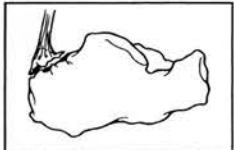
Location: Foot (81-85)

BONE: CALCANEUS (82)

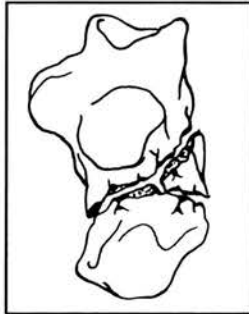


Types:

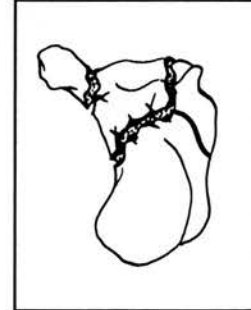
A. Avulsion or process or tuberosity (82-A)



B. Nonarticular body fractures (82-B)



C. Articular fractures involving posterior facet (82-C)



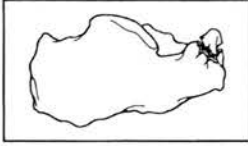
Groups:

Avulsion or process or tuberosity (82-A)

1. Anterior process (82-A1)

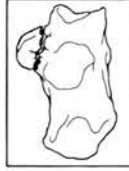
1. Noncomminuted (82-A1.1)

A



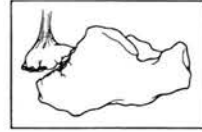
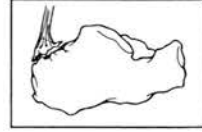
2. Medial, sustentaculum (82-A2)

1. Noncomminuted (82-A2.1)

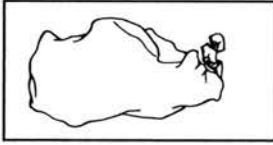


3. Tuberosity (82-A3)

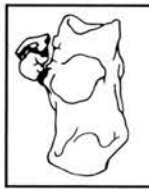
1. Noncomminuted (82-A3.1)



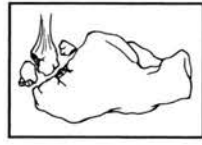
2. Comminuted (82-A1.2)



2. Comminuted (82-A2.2)



2. Comminuted (82-A3.2)

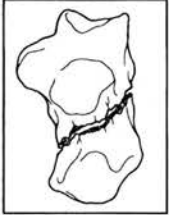


Groups:

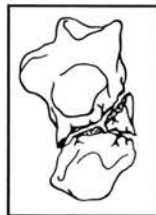
Nonarticular body fractures (82-B)

1. Noncomminuted (82-B1)

B



2. Comminuted (82-B2)



Groups:

Articular fractures involving posterior facet (82-C)

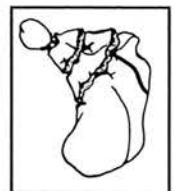
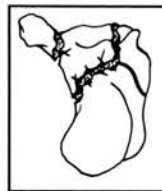
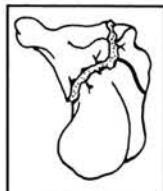
1. Nondisplaced (82-C1)

2. 2-part fractures (82-C2)

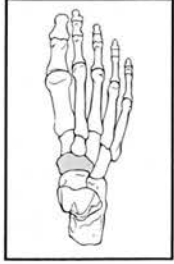
3. 3-part fractures (82-C3)

4. 4 or more parts (82-C4)

C



BONE: NAVICULAR (83)

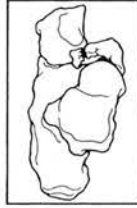


Types:

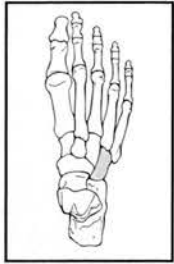
A. Noncomminuted (83-A)



B. Comminuted (83-B)

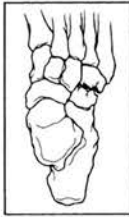


BONE: CUBOID (84)

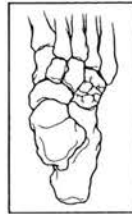


Types:

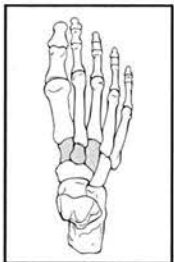
A. Noncomminuted (84-A)



B. Comminuted (84-B)



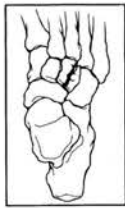
BONE: CUNEIFORM (85)



Types:

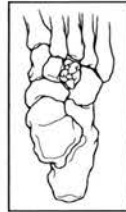
A. Noncomminuted (85-A)

- 1. Medial (85-A1)
- 2. Middle (85-A2)
- 3. Lateral (85-A3)



B. Comminuted (85-B)

- 1. Medial (85-B1)
- 2. Middle (85-B2)
- 3. Lateral (85-B3)



CRUSH, MULTIPLE FRACTURES (89)

Types:

A. Hind Foot (89-A)

B. Midfoot (89-B)

C. Forefoot (89-C)

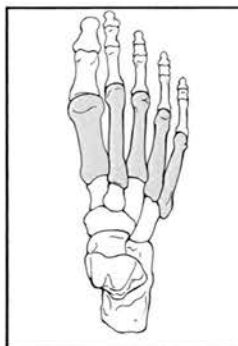
METATARSALS

BONE: METATARSALS (87)

Modifiers for metatarsals:

T, thumb toe (great) (1); I, index toe (2); L, long toe (3); R, ring toe (4); S, small toe (5).

Location: Metatarsals (87)



Types:

1. Metatarsal proximal and distal nonarticular and diaphysis non-comminuted (87-A)

2. Metatarsal proximal and distal partial articular diaphysis wedge comminution (87-B)

3. Metatarsal proximal and distal complete articular diaphysis comminuted (87-C)

Groups:

1. Metatarsal, proximal extra-articular (87-A1)

2. Metatarsal, diaphysis noncomminuted (87-A2)

3. Metatarsal, distal extra-articular (87-A3)

1. Metatarsal, proximal partial articular (87-B1)

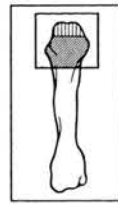
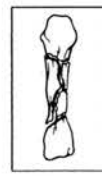
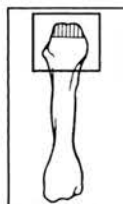
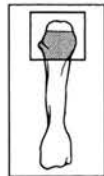
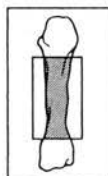
2. Metatarsal, diaphysis wedge (87-B2)

3. Metatarsal, distal partial articular (87-B3)

1. Metatarsal, proximal complete articular (87-C1)

2. Metatarsal, diaphysis comminuted (87-C2)

3. Metatarsal, distal complete articular (87-C3)



Subgroups and Qualifications:

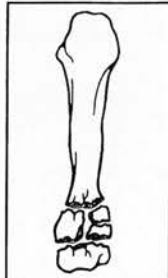
Metatarsal, proximal extra-articular (87-A1)

1. Noncomminuted (87-A1.1)

2. Comminuted (87-A1.2)

- (1) wedge
- (2) complex

A1



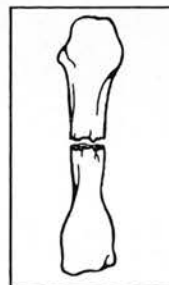
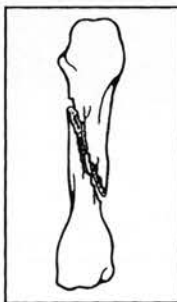
Metatarsal, diaphysis noncomminuted (87-A2)

1. Spiral (87-A2.1)

2. Oblique (87-A2.2)

3. Transverse (87-A2.3)

A2

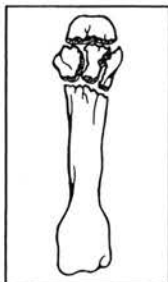
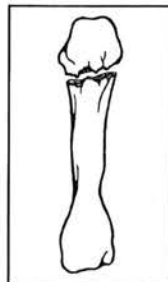


Metatarsal, distal extra-articular (87-A3)

1. Noncomminuted (87-A3.1)

2. Comminuted (87-A3.2)

A3



Metatarsal, proximal partial articular (87-B1)

1. Avulsion OR Split (87-B1.1)

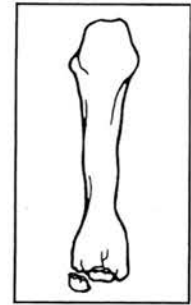
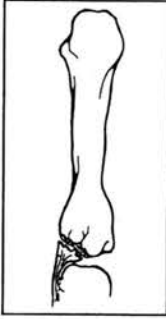
- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

2. Depression (87-B1.2)

3. Split/depression (87-B1.3)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

B1



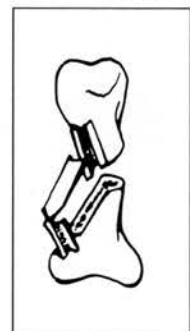
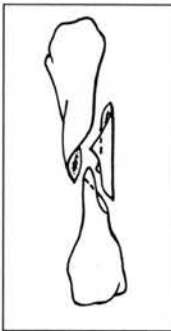
Metatarsal, diaphysis wedge (87-B2)

1. Spiral (87-B2.1)

2. Bending (87-B2.2)

3. Comminuted wedge (87-B2.3)

B2



Metatarsal, distal partial articular (87-B3)

1. Avulsion OR Split (87-B3.1)

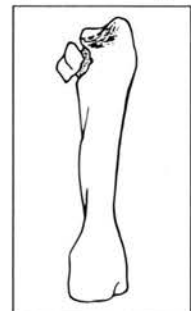
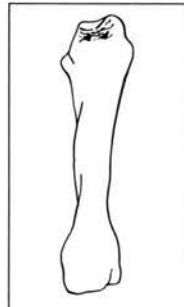
- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

2. Depression (87-B3.2)

3. Split/depression (87-B3.3)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

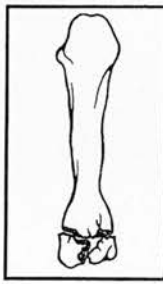
B3



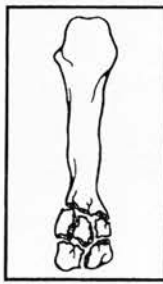
Metatarsal, proximal articular (87-C1)

1. Noncomminuted articular and metaphysis (87-C1.1)

C1



2. Noncomminuted articular, comminuted metaphysis (87-C1.2)



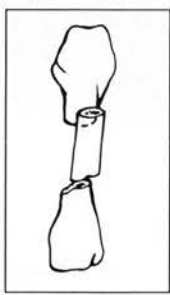
3. Comminuted articular (87-C1.3)



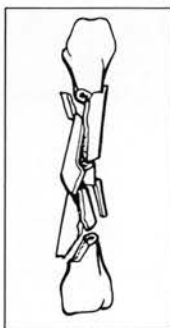
Metatarsal, diaphysis Comminuted (87-C2)

1. Segmental (87-C2.1)

C2



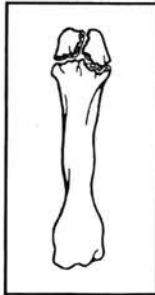
2. Complex comminuted (87-C2.2)



Metatarsal, distal articular (87-C3)

1. Simple articular/metaphysis (87-C3.1)

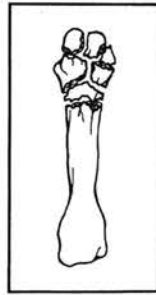
C3



2. Simple articular/comminuted metaphysis (87-C3.2)



3. Comminuted articular (87-C3.3)

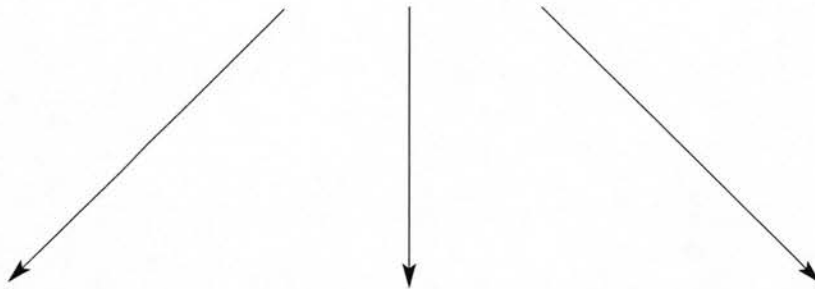
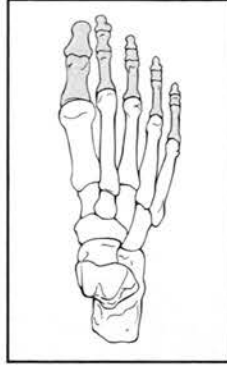


PHALANX - FOOT

BONE: PHALANX (88)

Modifiers for phalanx:
 T1 and T2, thumb toe
 1/2; N1, N2 and N3,
 index toe 1/2/3; M1,
 M2 and M3, middle toe
 1/2/3; R1, R2 and R3,
 ring toe 1/2/3; L1, L2
 and L3, little toe 1/2/3.

Location: Phalanx (88)

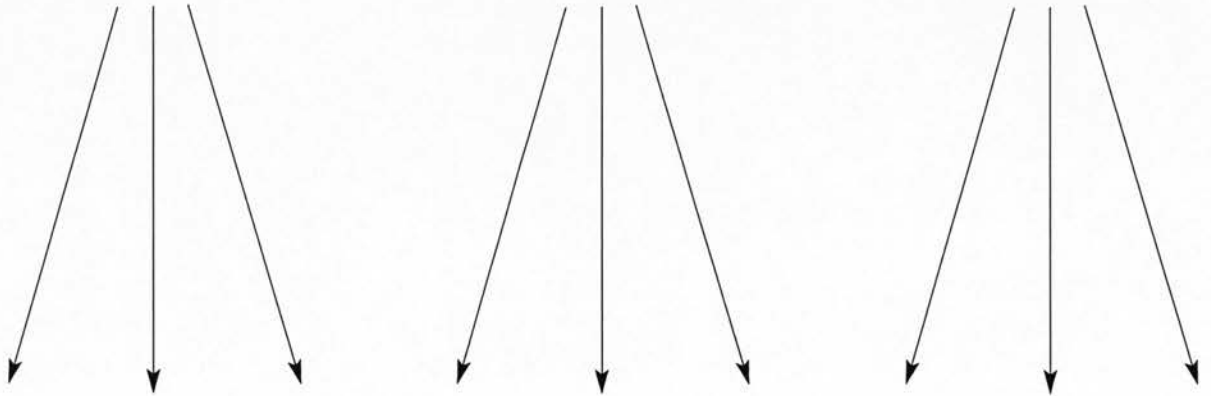


Types:

A. Phalanx proximal and distal extra-articular and diaphysis noncomminuted (88-A)

B. Phalanx proximal and distal partial articular and diaphysis wedge comminution (88-B)

C. Phalanx proximal and distal complete articular and diaphysis comminuted (88-C)



Groups:

1. Phalanx, proximal extra-articular (88-A1)

2. Phalanx diaphysis, non-comminuted (88-A2)

3. Phalanx, distal extra-articular (88-A3)

1. Phalanx, proximal partial articular (88-B1)

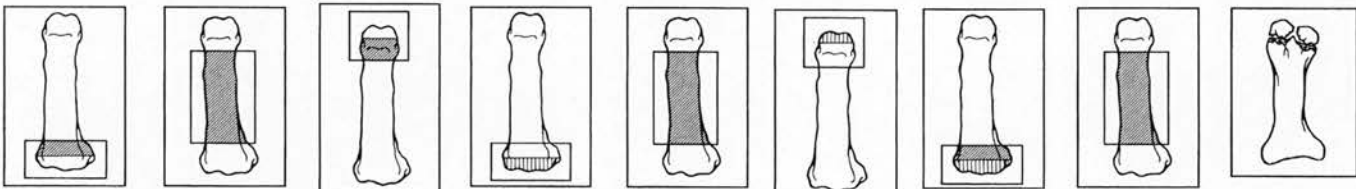
2. Phalanx, diaphysis wedge (88-B2)

3. Phalanx, distal partial articular (88-B3)

1. Phalanx, proximal complete articular (88-C1)

2. Phalanx, diaphysis comminuted (88-C2)

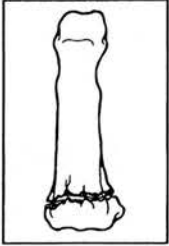
3. Phalanx, distal complete articular (88-C3)



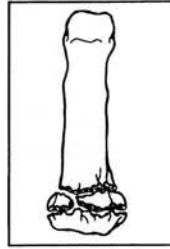
Subgroups and Qualifications:

Phalanx, proximal extra-articular (88-A1)

1. Noncomminuted (88-A1.1)



2. Comminuted (88-A1.2)



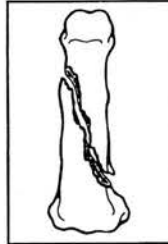
A1

Phalanx, diaphyseal noncomminuted (88-A2)

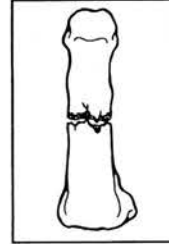
1. Spiral (88-A2.1)



2. Oblique (88-A2.2)



3. Transverse (88-A2.3)



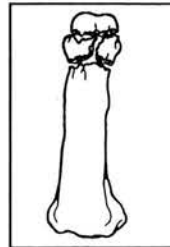
A2

Phalanx, distal extra-articular (88-A3)

1. Noncomminuted (88-A3.1)



2. Comminuted (88-A3.2)



A3

Phalanx, proximal partial articular (88-B1)

1. Avulsion OR Split (88-B1.1)

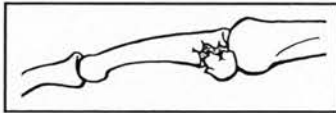
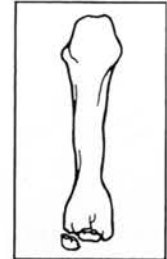
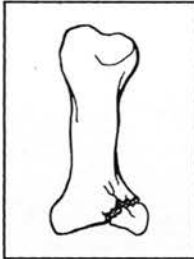
- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

2. Depression (88-B1.2)

3. Split/depression (88-B1.3)

- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

B1



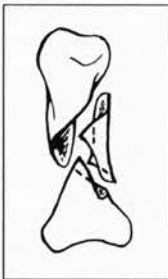
Phalanx, diaphysis wedge (88-B2)

1. Spiral (88-B2.1)

2. Bending (88-B2.2)

3. Fragmented (88-B2.3)

B2



Phalanx, distal partial articular (88-B3)

1. Avulsion OR Split (88-B3.1)

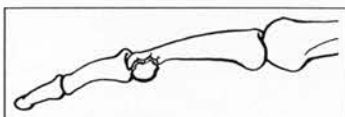
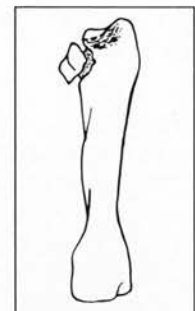
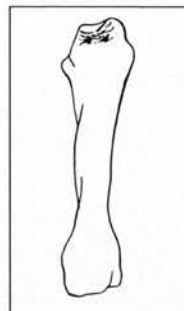
- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

2. Depression (88-B3.2)

3. Split/depression (88-B3.3)

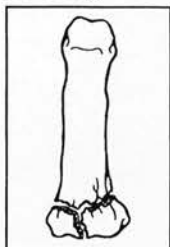
- (1) unicondyle medial
- (2) unicondyle lateral
- (3) coronal split volar fragment
- (4) coronal split dorsal fragment

B3

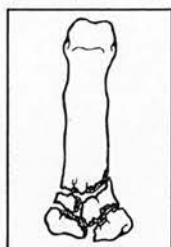


Phalanx, proximal complete articular (88-C1)

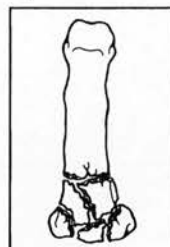
1. Noncomminuted articular/
metaphysis (88-C1.1)



2. Noncomminuted articular/comminuted metaphysis (88-C1.2)



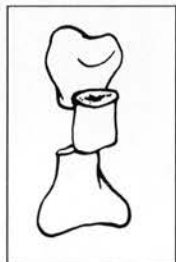
3. Comminuted articular and metaphysis (88-C1.3)



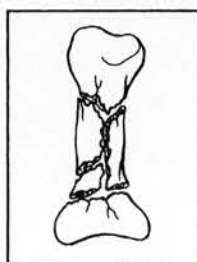
C1

Phalanx, diaphysis comminuted (88-C2)

1. Segmental (88-C2.1)



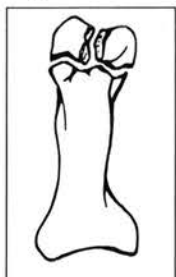
2. Complex comminuted (88-C2.2)



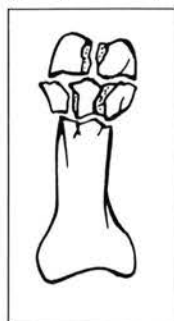
C2

Phalanx, distal articular (88-C3)

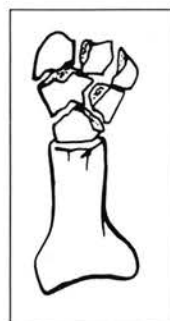
1. Noncomminuted articular/meta-
physis (88-C3.1)



2. Noncomminuted articular comminuted metaphysis (88-C3.2)



3. Comminuted articular (88-C3.3)



C3