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THE CHARACTERISTICS OF FACIAL FRACTURES AND ASSOSIATED INJURIES IN GERIATRIC FACIAL TRAUMA PATIENTS

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To my Family

Contents

List of original publications

The present thesis is based on the following original publications, which are referred to in the text by their Roman numerals:

I Toivari M, Helenius M, Suominen AL, Lindqvist C, Thorén H. Etiology of facial fractures in elderly Finns during 2006 – 2007. Oral Surg Oral Med Oral Pathol Oral Radiol. 2014;118(5): 539-545.

II Toivari M, Suominen AL, Lindqvist C, Thorén H. Among Patients with Facial Fractures, Geriatric Patients Have an Increased Risk for Associated Injuries. J Oral Maxillofac Surg. 2016;74(7): 1403-1409.

III Toivari M, Suominen AL, Apajalahti S, Lindqvist C, Snäll J, Thorén H. Isolated Orbital Fractures Are Severe Among Geriatric Patients. J Oral Maxillofac Surg. 2018;76(2): 388-395.

IV Toivari M, Snäll J, Suominen AL, Apajalahti S, Lindqvist C, Thorén H. Associated Injuries are Frequent and Severe Among Geriatric Patients with isolated Zygomatico-Orbital Fractures. J Oral Maxillofac Surg. 2019;77(3): 565-570.

Abbreviations

ACT	Anticoagulation and Trauma
AI	Associated injury
AIS	Abbreviated Injury Scale
CI	Confidence interval
CT	Computed tomography
GCS	Glasgow Coma Scale
GMP	Globe malposition
FISS	Facial Injury Severity Score
H.T.	Hanna Thorén (author in articles I-IV)
ICD	International Classification of Diseases
ICU	Intensive care unit
IOB	Inferior orbital buttress
IOF	Inferior orbital fissure
ISS	Injury Severity Score
M.T.	Miika Toivari (author of articles I–IV)
MVA	Motor vehicle accident
OR	Odds ratio
PL	Posterior ledge
RBH	Retrobulbar hematoma
RR	Risk ratio
S.A.	Satu Apajalahti (co-author of articles III and IV)
SAV	Subarachnoid hemorrhage
SBH	Subdural hemorrhage
TBI	Traumatic brain injury
TRISS	Trauma Revised Injury Severity Score
UN	United Nations
WHO	World Health Organization
ZMO	Zygomatico-orbital

Abstract

The aims of the present study were to identify the characteristics of facial fractures in geriatric patients and to compare them with younger adults. The hypotheses were that the causes and resulting types of facial fractures are different, and that geriatric patients are more severely injured than younger controls.

The present study focused on three different patient populations, diagnosed and treated for facial fractures at a level I trauma center and at the Department of Oral and Maxillofacial Diseases, Helsinki University Hospital, Helsinki, Finland. The study included patients with all types of facial fractures (Studies I and II), with a unilateral orbital fracture (Study III), and with a unilateral ZMO fracture (Study IV).

The commonest cause of facial fractures in geriatric patients was falling on the ground, whereas younger adults commonly sustained their injuries due to assault (Studies I to IV). Midfacial fractures were significantly more common in geriatric than younger adult patients (Study I). Orbital fractures were significantly more often extensive among geriatric than younger adult patients (Study III). Associated injuries (AIs) in general, multiple AIs, and mortality were significantly more frequent among the elderly when compared to younger controls (Study II). In patients diagnosed with isolated ZMO fractures, AIs in general and traumatic brain injuries (TBI) in particular were significantly more frequent among the geriatric than the younger control group (Study IV).

The causes and resulting types of facial injuries differ between geriatric patients and younger adults, and midfacial fractures need to be meticulously excluded in geriatric patients. The frequency and severity of AIs in geriatric facial trauma requires systematic trauma assessment, repeated examination of patient's condition, and care in collaboration with several specialties.

1. Introduction

People around the world are living longer than before. Globally, the average life expectancy from birth reached 72.0 years by 2016 (WHO 2016). The rising life expectancy will increase the proportion and burden of elderly patients in healthcare in general, and in traumatology. In addition to changing age distribution in traumatic injuries, geriatric patients differ from younger adults, for instance when comparing the causes and severity of injuries, as well as the comorbidities related to injuries at different ages.

According to the literature, TBI-associated health comorbidities in geriatric patients are more often related to cardiovascular, metabolic, and nutritional factors, whereas in younger adults the health comorbidities are more often mental disorders and nervous diseases (Chan, Mollayeva et al. 2017). Secondly, on average, one in three seniors, aged at least 65 years, fall at least once a year (Tilvis, Pitkälä et al. 2016), which reflects the notably higher rate of falling on the ground as a cause of different traumatic injuries in geriatric patients when compared to younger adult patients (Sterling, O'Connor et al. 2001, Hannan, Waller et al. 2004).

Thirdly, the literature has shown that geriatric patients are more severely injured than younger adults. In orthopedic major injuries, such as long bone or pelvic fractures, the injuries are more often caused by MVAs in younger adults than in the elderly. Previous research has also shown that in major injuries of this type, the elderly more often die due to their injuries, although the need for critical care is reported to be less frequent in geriatric patients than younger controls (Herron, Hutchinson et al. 2017).

The reported change in the age distribution (WHO 2016, Tilastokeskus 2012) is likely to result in an increasing number of geriatric trauma patients in general and facial injuries in particular when compared to previous decades. Due to the growing frequency of geriatric trauma patients, their differences compared to other age groups, and the scarcity of publications focusing on geriatric facial trauma, the characteristics of geriatric facial trauma need to be investigated in more detail.

2. Review of the literature

2.1 Geriatric trauma

People aged at least 60 years are the fastest growing part of the population worldwide (UN 2012), and as estimated by Hildenbrand et al., the proportion of geriatric patients will rise on average by 40% among all types of trauma patients by the 2050s (Hildebrand, Pape et al. 2016). In a recently published study on the Japanese population, the proportion of elderly trauma patients had already reached 59.7% among patients with all types of traumatic injuries (Kojima, Endo et al. 2019).

The frequency of geriatric patients with facial traumas has varied from 0.2% to 14.5% when patients of all ages are included (Martinez, Como et al. 2014, Royan, Hamid et al. 2008, Kloss, Tuli, Hachl et al. 2007, Gerbino, Roccia et al. 1999, Zelken, Khalifian et al. 2014). When children and teenagers under 16 years are excluded, the proportion of elderly has been reported to rise to 31.5% (Imholz, Combescure et al. 2014). In greater detail, a study by Gerbino et al. revealed that the proportion of geriatric patients, aged at least 60 years, rose from 7% to 12.2% within a 10-year period from 1987 to 1996 (Gerbino, Roccia et al. 1999). During the same period, a Finnish population-based study published by Kontio et al. demonstrated a parallel, although more gradual rise from 5.3% to 8.6% in the frequency of geriatric facial fractures between 1981 and 1997 (Kontio, Suuronen et al. 2005). Yet, an increasing frequency of geriatric facial trauma can be expected in the 21th century.

An Australian population-based study by Velayutham et al. predicted that the proportion of facial trauma patients aged over 60 years would rise in Australia from 8.5% to 12.2% between 2010 and 2034 due to the increase in the senior population from 20% to 26% by 2034 (Velayutham, Sivanandarajasingam et al. 2013). European and American population-based studies have already demonstrated the same increase (Martinez, Como et al. 2014, Royan, Hamid et al. 2008, Kloss, Tuli, Hachl et al. 2007, Gerbino, Roccia et al. 1999, Zelken, Khalifian et al. 2014, Imholz, Combescure et al. 2014, Kontio, Suuronen et al. 2005). However, the proportion of geriatric facial trauma patients is likely to rise further in Finland, as it has been estimated that the proportion of elderly people, aged at least 65 years, will increase from the present 21.4% to 28% by 2060 (Tilastokeskus 2012).

2.2 The definition of a geriatric age

The definition of a geriatric age is ambiguous. According to the World Health Organization (WHO), every patient aged at least 50 to 55 years should be referred to under study purposes as an elderly person in studies conducted in developing parts of world, such as Africa (WHO 2002). On the contrary, according to the UN, every citizen at least 60 years old should be referred to as an elderly person (UN 2012).

As discussed in the statement by WHO, the boundary for an elderly age has strongly been related to socio-economic factors such as the onset of retirement in industrialized countries (WHO 2002). For instance, in Finland, the onset of retirement has on average been 65 years, but people may have been able to step aside from working life and receive a part-time pension a few years earlier. Moreover, the socio-economic boundaries are continuing to change, as it has been estimated that the average age of retirement will be 67 years by 2050 (EKT 2018).

The definition of a geriatric age should be based to the assessment of physiological and non-physiological changes, and the patient's capability to function. Examples of these types of physiological changes are the increase in the proportion of body fat, the decrease in diastolic blood pressure and rise in systolic blood pressure, and the reduction in muscle mass that take place during life (Tilvis, Pitkälä et al. 2016). Differing from the physiological changes, the potentially underlying frailty needs to be recognized as an aberrant process unrelated to healthy aging (Tilvis, Pitkälä et al. 2016, Fried, Tangen et al. 2001). According to Fried et al., frailty is a condition defined by five major criteria, i.e. 1) the presence of unintentional weight loss, 2) patient-reported exhaustion, 3) general weakness, 4) a reduced walking speed, and 5) reduced physical activity (Fried, Tangen et al. 2001).

The WHO has estimated that one in ten of the elderly are affected by frailty (WHO 2015). However, according to a study by Song et al., up to 25.3% of the elderly, at least 65 years old, are affected by frailty, and the level of frailty already starts to rise from the ages of 65 to 70 years (Song, Mitnitski et al. 2010). From the traumatology point of view, frailty increases the risk of falling (Cheng, Chang 2017), but it also increases the risk of post-operative complications such pneumonia, wound infections, and urinary tract infections, and associates with prolonged hospitalization, sepsis, and an increased risk of mortality during hospitalization (Orouji Jokar, Ibraheem et al. 2016, McIsaac, Moloo et al. 2017).

Even though different criteria for a geriatric age have been presented, the literature supports the definition of a geriatric age as starting from 65 years, even in industrialized countries, to cover, for instance, the different levels of frailty (Song, Mitnitski et al. 2010).

2.3 Falling and geriatric trauma

One in three patients aged at least 65 years fall on the ground once a year, and 15% of the elderly fall recurrently. The rate of falling rises to over 50% among those geriatric patients who are at least 80 years old (Stalenhoef, Crebolder et al. 1997).

This reflects the causes of trauma, with falling on the ground being the commonest cause of injury (48.0–55.0%) among geriatric patients at least 65 years old (Hannan, Waller et al. 2004, Sterling, O'Connor et al. 2001, Ferrera, Bartfield et al. 2000). The rate of falling reported in the literature is notably higher in geriatric patients than in younger patients under 65 years old (7.0–29.7%) (Sterling, O'Connor et al. 2001, Hannan, Waller et al. 2004). Although the rate of falling in geriatric trauma has been reported in the literature, we do not know enough about the causes of geriatric facial injuries.

2.3.1 Risk factors for elderly falling

The majority of fall related injuries of different types are sustained indoors or in the home environment (Rosen, Mack et al. 2013, THL 2018), whereas several external and internal risk factors over the chronological age predispose geriatric patients to falling (Tilvis, Pitkälä et al. 2016, Rubenstein, Josephson et al. 1994, American Geriatrics Society 2001). Factors increasing the risk of external, environment-dependent falls can be divided into uneven and slippery surfaces, carpets and rugs, dim lightning, and different types of obstacles in the environment (Tilvis, Pitkälä et al. 2016).

The internal risk factors for falling include chronic illnesses that predispose to falling and syncope, medications (particularly pharmaceuticals affecting the central nervous system and balance), alcohol abuse, poor coordination, protracted reactivity, weakened eyesight and hearing, and frailty (Tilvis, Pitkälä et al. 2016, Aira, Hartikainen et al. 2008, Immonen, Sirpa, Valvanne et al. 2011a, Immonen, S., Valvanne et al. 2011b, Rubenstein, Josephson et al. 1994, Campbell, Spears et al. 1990, Cheng, Chang 2017, de Vries, Peeters et al. 2013). According to a study by Song et al., frailty is more frequent among females (25.3%) than males (18.6%), whereas the difficulty level rises as a function of age from 65 years onwards (Song, Mitnitski et al. 2010). Frailty was found to especially increase the risk of recurrent falling, particularly among those aged at least 75 years, within a one-year follow-up (de Vries, Peeters et al. 2013).

In relation to the regular usage of medications, polypharmacy (the regular usage of six medications or more) is a factor reported to increase the fall risk (Carpenter, Avidan et al. 2014). Attention also needs to be paid to medications affecting the central nervous system, and according to the Beers criteria, the medications to be avoided in elderly patients with a history of falls or fractures include 1) antiepileptics, 2) antipsychotics and benzodiazepines, 3) short-term sleeping medications ("Z-medications"), 4) antidepressants, and 5) opioids (American Geriatric Society 2019).

2.3.2 Severity of fall-related geriatric injuries

The literature has shown that out of all falls, 1–10% result in fractures and 1–36% in traumatic brain injuries or other severe soft tissue injuries, as presented by Rubenstein et al. in 1994 (Rubenstein, Josephson et al. 1994). The commonest types of fall-related injuries reported in the elderly are extremity injuries (46.8–70.5%) (Spaniolas, Cheng et al. 2010, Bergeron, Clement et al. 2006) and head injuries (including both traumatic brain injuries and facial trauma) (50.6–66.0%) (Ayoung-Chee, McIntyre et al. 2014, Gowing, Jain 2007).

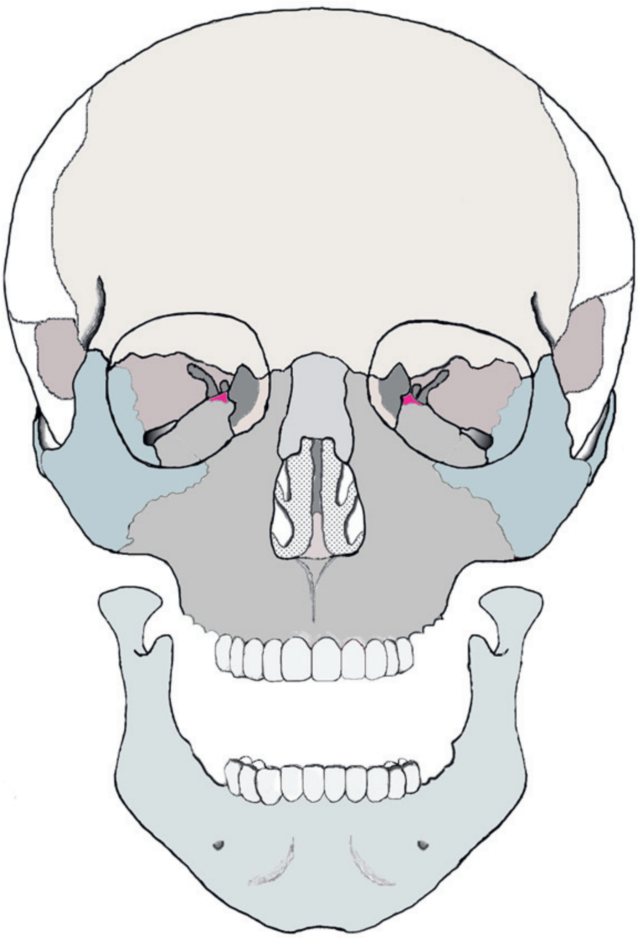
Although falling on the ground is usually a low-energy mechanism, falls are a major predictor of mortality in geriatric patients (Sampalis, Nathanson et al. 2009). A study by Sterling et al. demonstrated that falls of the same level were more frequently related to a higher Injury Severity Score (ISS > 15) in geriatric patients (30%), aged at least 65 years, than in patients under 65 years old (4%) (Sterling, O'Connor et al. 2001). The severity of a geriatric falls can be considered equivalent to MVAs, when comparing the abovementioned study with the results presented by Bauza et al., who compared the severity on the ISS scale in MVA-related injuries. Indeed, Bauza et al. concluded that in MVAs, the average ISS was 14.6 for patients over 70 years, whereas an average ISS from 8.6–10.2 was found for patients under 54 years old (Bauzá, Lamorte et al. 2008).

When comparing the mortality rate in the studies of Bauzá et al. and Sterling et al., similarities can be found, even though the trauma mechanisms differed. Mortality due to a same-level fall was 10 times more frequent in patients aged at least 65 years (25%) when compared patients under 65 years old (2.5%) (Sterling, O'Connor et al. 2001). This ratio corresponds to the results of Bauza et al., who concluded that the rate of MVA-caused mortality was 17.1% in patients over 70 years old but only 2.3–3.2% in patients aged under 54 years (Bauzá, Lamorte et al. 2008). Clearly, falls among the elderly are a severe cause of injuries (Sterling, O'Connor et al. 2001). However, comparative investigations on the severity of geriatric facial trauma in association with falls are lacking.

2.4 The facial skeleton and classification of facial fractures

The facial skeleton is formed by the union of the frontal, sphenoid, ethmoid, zygomatic, lacrimal, vomer, palatine and nasal bones, as well as the maxilla and mandible (Norton, Netter 2012, Netter 2011), as presented in Figure 1.

For the precise location of facial fractures, the facial skeleton can be divided into three thirds as follows: 1) the upper facial third, comprising the frontal bone, 2) the middle third, comprising the central midfacial bones, including the maxilla, the nasoethmoid complex, and the zygomatic bone, and 3) the lower facial third, comprising the mandible (Pappachan, Alexander 2012). Based on the distribution of solitary injuries, fractures can be further classified as isolated mandibular, isolated zygomatico-orbital (i.e., tripoid zygomatic fracture or isolated zygomatic arch fracture), isolated orbital (i.e., isolated



Abbreviations: The facial skeleton ☐ frontal bone, ☐ sphenoid bone, ☐ ethmoid bone, ☐ zygomatic bone, ☐ lacrimal bone, ☐ vomer, ☐ palatine bone (orbital process shown only), ☐ nasal bone, ☐ maxilla, ☐ mandible

Figure 1. The facial skeleton (modified from Study I).

orbital floor, medial wall, or roof fracture, or a combination of these), isolated nasal, isolated wall of the maxillary sinus, extensive midfacial (i.e., LeFort I–III, naso-orbito-ethmoidal, or multiple midfacial fractures, or a combination of those), isolated upper third (i.e., fractures of the frontal sinus, anterior skull base, or both), combined (i.e., mandibular + midfacial fracture, midfacial + upper third fracture, or panfacial fracture extending to all facial thirds), and isolated dentoalveolar injuries. There is a need to determine which types of fractures geriatric patients sustain, due to the lack of published information.

Within the facial region, among the most complex structures according to their three-dimensional structures are the zygomatic bone and orbit (Norton, Netter 2012).

2.4.1 The zygomatic bone and ZMO fracture

The outer prominence and the center of the lateral force line of the midfacial region is formed by the zygoma, which is a tripod-shaped bone cranially uniting with the frontal bone (frontozygomatic suture), inferior-medially with the maxilla (zygomaticomaxillary suture), and posteriorly with its arch to the temporal bone. In addition, the zygoma is involved in the formation of the orbital lateral wall and the anterolateral part of the orbital floor (Norton, Netter 2012).

Several classification systems have been developed for the analysis and treatment planning of ZMO fractures, taking into account both fracture translation and rotation (Larsen, Thomsen 1978, Gillies, Kilner et al. 1927, Knight, North 1961, Rowe, Killey 1968). For the simplification of ZMO fractures, injuries can be divided according to the anatomical location of the fracture line(s) into 1) tripod ZMO fractures (comprising the lateral orbit, inferior orbit, anterior and posterior maxillary wall, and zygomatic arch), 2) isolated arch fractures (comprising only the zygomatic arch), and 3) ZMO fractures without arch involvement, as presented in Figure 1. The characteristics of ZMO fractures need to be investigated in geriatric patients, due to the lack of published information.

2.4.2 The orbit and orbital fracture

In the mid-facial region, the orbit can be considered as the most complex structure. The orbit is formed by the union of seven different bones: the frontal bone (orbital roof, superior part of the orbital medial wall), the zygoma (anterior part of the lateral wall, anterior lateral floor), the sphenoid bone (posterior lateral and medial walls), the maxilla (orbital floor), the lacrimal bone (anterior medial wall), the ethmoid bone (medial wall), and the orbital process of the palatine bone (posterior shelf) (Netter 2011, Norton, Netter 2012, Kunz, Audigé, Cornelius, Buitrago-Téllez, Frodel et al. 2014a, Kunz, Audigé, Cornelius, Buitrago-Téllez, Rudderman et al. 2014b).

The orbit has three anatomical intraorbital landmarks, which have a crucial role in the support of corrective surgery, i.e. the inferior orbital fissure (IOF), intraorbital buttress (IOB), and posterior ledge (PL). The IOF is a fissure demarcated between the lateral orbital wall and orbital floor and uniting posteriorly with the superior orbital fissure. The IOB is the support point, formed by the union of the medial wall and orbital floor. The posterior shelf is the surgical support point, formed by the projection of the palatine bone, which merges in the posterior part of the orbit with the intraorbital fissure (Kunz, Audigé et al. 2014). Figure 2 presents the above-described structures.

The orbit needs to be evaluated as a pear-shaped socket, the apex of which is directed to the midline of the neurocranium, and further, the location of a fracture needs to be assessed according to the orbital thirds (Jaquiéry, Aeppli et al. 2007), illustrated in Figure 2, to evaluate the plausibility of the fracture causing asymmetric globe malposition (GMP) or functional diplopia (Ellis 2012, Zhang, Zhang et al. 2012). A comprehensive investigation of geriatric orbital fractures needs to be conducted to improve knowledge of orbital trauma in geriatric patients in particular.

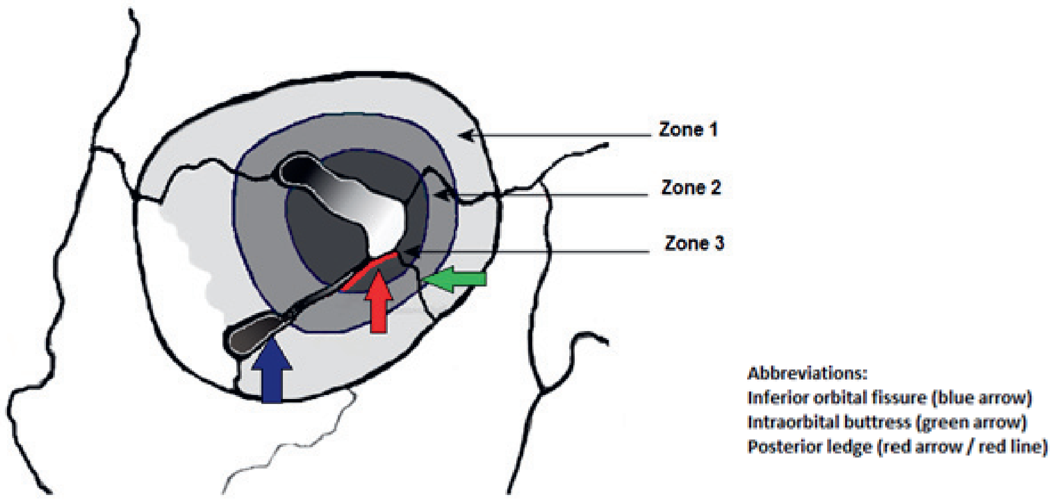


Figure 2. Orbital zones and intraorbital anatomical landmarks (published in Study III).

3. Aims of the study

The aims of the present study were to investigate facial fractures and injuries associated with them in geriatric patients, and to clarify whether fractures and associated injuries in geriatric patients differ from those in younger adults. The hypotheses were that the causes and types of facial fractures in geriatric patients are different from those of younger adults, and that associated injuries are more frequent and severe in geriatric patients.

The specific aims were to investigate:

1. The gender and age of patients, time of injury, and causes of facial fractures (Studies I, III, and IV);
2. The types and clinical features of facial fractures (Studies I, III, and IV);
3. The Associated injuries outside the facial region in patients diagnosed with facial fractures (Studies II and IV).

4. Patients and methods

The present study focused on geriatric trauma patients, diagnosed and treated for facial fractures at Töölö Hospital, and additionally at the Department of Oral and Maxillofacial Diseases, Helsinki University Hospital, Helsinki, Finland. Töölö Hospital is a level I trauma center, treating 20,000 trauma patients annually and having the specialties in the field of oral and maxillofacial surgery, orthopedics and traumatology, neurosurgery, plastic surgery, and hand surgery.

The Department of Oral and Maxillofacial Diseases is the department providing oral and maxillofacial surgery and clinical dental care (oral diseases) in the district of Helsinki and province of Uusimaa, having 24-hour duty in oral and maxillofacial surgery and responsible for the diagnosis and treatment of facial trauma at the Emergency Department of Töölö Hospital.

4.1 Study design

Figure 3 presents the study design. In Studies I and II, the electronic medical records of all geriatric patients, aged 65 years or more, admitted to the Level I Trauma Center at Töölö Hospital, Helsinki, from January 1, 2006, to December 31, 2007, were overviewed and analyzed retrospectively. All radiological imaging studies on the facial region were analyzed to determine the precise registration of maxillofacial fracture(s). The study group included those geriatric patients diagnosed with facial fracture(s).

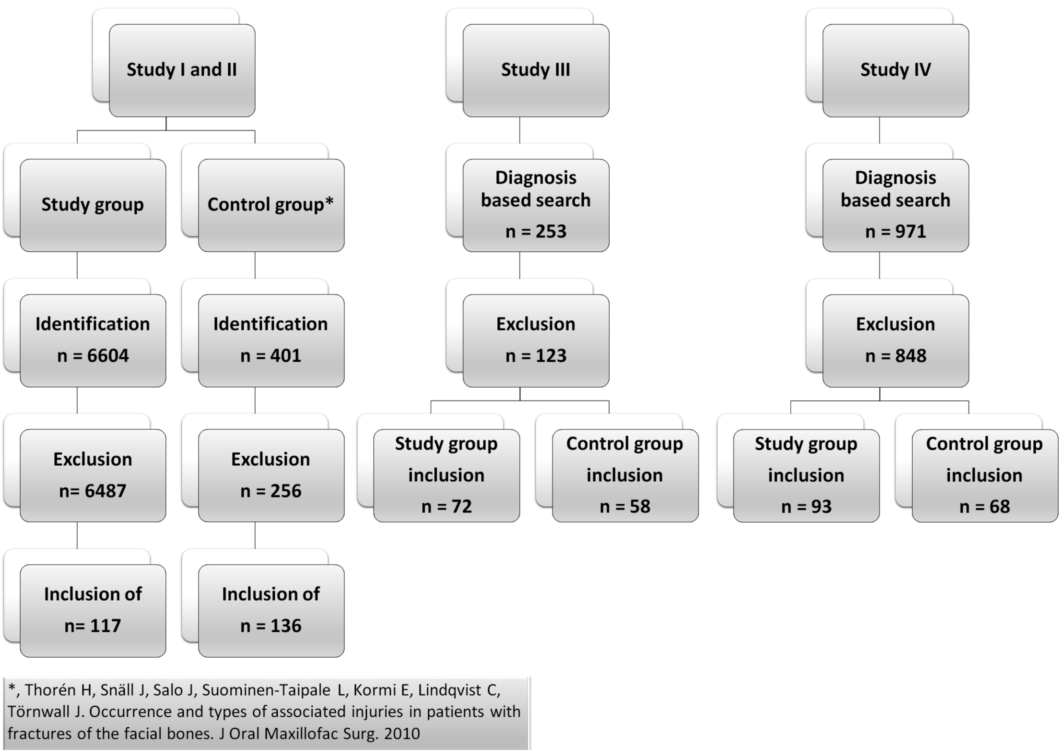


Figure 3. Study design for examination of the characteristics and severity of facial fractures in geriatric patients.

In Studies I and II, a retrospective evaluation and analysis of the electronic medical records from a previously published data set during a 2-year time period from January 1, 2003, to December 31, 2004 was planned and carried out (Thorén, Snall et al. 2010). All radiological imaging studies on the facial region were analyzed to determine the precise registration of maxillofacial fracture(s). The studies included those patients aged 20 to 50 years diagnosed with and treated for facial fractures and whose complete medical reports were electronically available from January 1, 2004, to December 31, 2004.

In Study III, a diagnosis-based electronic medical record search was planned and carried out retrospectively from patient registers during a 9-year time period, from January 1, 2006, to December 31, 2014. The diagnosis-based search was conducted with International Classification of Diseases (ICD) codes S02.30 (fracture of an orbit, closed) and S02.31 (fracture of an orbit, open). All patients with either appointed diagnosis were identified and taken into the evaluation of medical reports and radiological examinations (computed tomography of the facial bones). The study included those patients diagnosed with an isolated unilateral orbital fracture who were aged at least 65 years (study group) or 20 to 50 years (control group). Patients excluded from Study III were the following: 1) patients diagnosed with any other facial fractures, 2) patients with an orbital fracture extending to the orbital rim, 3) patients with a bilateral orbital fracture, and 4) patients for whom computed tomography (CT) scans for evaluation in all 3 planes were not available (i.e., axial, coronal, and sagittal).

In Study IV, a diagnosis-based electronic medical record search was planned and carried out retrospectively from patient registers during a 7-year period, from January 1, 2010, to December 31, 2016. The diagnosis-based search was conducted with ICD codes S02.40 (fracture of the maxilla and/or zygoma, closed) and S02.41 (fracture of the maxilla and/or zygoma, open). All patients with either appointed diagnosis were identified and taken into the evaluation of medical reports and radiological examinations (computed tomography of the facial bones). The study included those patients diagnosed with an isolated unilateral ZMO fracture who were aged at least 65 years (study group) or 20 to 30 years (control group). Patients with any other facial fracture(s), except an associated fracture of the coronoid process, were excluded from the study.

4.2 Study populations

Studies I and II included a total of 117 geriatric and 136 younger adult patients diagnosed and treated for all types of facial fractures. Study III included 72 geriatric patients and 58 younger controls diagnosed and treated for a unilateral orbital fracture. Study IV included 93 geriatric patients and 68 younger controls diagnosed and treated for an isolated unilateral ZMO fracture.

4.3 Outcome variables

4.3.1 Gender and age of patients, time of injury, and causes of facial fractures (Studies I, III, and IV)

For all patients enrolled in Studies I–IV, the cause of injury was registered and classified as follows: 1) fall on the ground, 2) MVA, 3) fall from height, 4) bicycle accident, 5) assault, 6) hit by a blunt object, 7) sports-related, and 8) gunshot accident. Regarding MVAs, the nature of the accident was also registered, i.e. whether the patient was in the vehicle or hit by a vehicle. The presence of intoxication by alcohol during the trauma diagnosis was based on breathalyzer-confirmed measurement. For all patients enrolled in Study I, the time of the injury was registered and analyzed as the day of the week and month.

4.3.2 Anatomical distribution of facial fractures (Study I)

For all patients enrolled in Study I, one of the following nine groups of facial fracture types was assigned for each patient: 1) isolated mandibular fractures (≥1 injury); 2) isolated zygomatico-orbital fractures (i.e., tripod zygomatic fracture or isolated zygomatic arch fracture); 3) isolated orbital fractures (i.e., isolated orbital floor, medial wall, or roof fracture, or a combination of these); 4) isolated nasal fractures; 5) isolated fractures of the wall of the maxillary sinus; 6) extensive midfacial fractures (i.e., LeFort I–III, naso-orbito-ethmoidal, or multiple midfacial fractures, or a combination of these); 7) isolated upper third fractures (i.e., fractures of the frontal sinus, anterior skull base, or both); 8) combined fractures (i.e., mandibular + midfacial fracture, midfacial + upper third fracture, or panfacial fracture extending to all facial thirds); and 9) isolated dentoalveolar injuries.

The facial fractures were further classified into one of the following four subgroups of fracture locations according to the facial third in the cranio-caudal direction: 1) isolated upper facial third, 2) isolated middle facial third, 3) isolated lower facial third, 4) combined (i.e., combination of at least two facial thirds).

4.3.3 Characteristics of isolated unilateral orbital fractures (Study III)

For all patients enrolled in Study III, one of the following four groups of orbital fracture types was assigned for each patient: 1) isolated fractures of the orbital floor, 2) isolated fractures of the medial orbital wall, 3) combined orbital fractures (i.e. floor plus medial or lateral wall, medial plus lateral wall, floor plus medial wall plus roof of orbit), or 4) other (i.e. isolated fractures of the orbital roof or lateral wall).

From the CTs, the associated orbital zone(s) in the anteroposterior direction, the fracture area (cm^2), the presence and degree of fracture dislocation (mm), and the involvement of relevant anatomic intraorbital landmarks were also evaluated. The associated zones were classified as follows: zone 1, anterior orbital third; zone 2, middle orbital third; and zone 3, posterior orbital third (Figure 2). The fractured area was further classified for each patient as follows: 1) fissure, 2) less than 2 cm^2, 3) 2 cm^2 or greater. The involvement of relevant anatomical landmarks was registered for each patient from the following: 1) the posterior orbital ledge, 2) the intraorbital buttress, 3) the inferior orbital fissure (Figure 2).

For patients enrolled in Study III, the diagnosis of severe ocular injuries was based on either clinical examination (consultation with the on-duty ophthalmologist) or CT findings in relation to intraorbital hemorrhages.

4.3.4 Characteristics of isolated unilateral ZMO fractures (Study IV)

For all patients enrolled in Study IV, one of the following three categories of ZMO fracture types was assigned for each patient: 1) tripod ZMO fractures (comprising the lateral orbit, inferior orbit, anterior and posterior maxillary wall, and zygomatic arch), 2) isolated arch fractures (comprising only the zygomatic arch), and 3) ZMO fractures without arch involvement.

The clinical parameters 1) restricted maximal mandibular opening and 2) asymmetry of the zygomatic prominence were based on the clinical registrations and markings in the medical records of each patient under the primary post-traumatic evaluation by the on-duty maxillofacial surgeon.

For all patients enrolled in Study IV, ZMO fracture dislocation was determined and classified dichotomously as present or absent.

4.3.5 Associated injuries outside the facial region (Studies II and IV)

For all patients enrolled in Studies II and IV, the presence of an AI was the primary outcome, defined as any major injury outside the facial region, excluding brain concussions, wounds, and other minor soft tissue injuries such as bruises. The precise AI site was recorded and further classified according to the affected organ system in Studies II and IV as 1) brain, 2) chest, 3) abdomen, 4) spine, 5) limbs, and for patients in Study IV additionally as 6) neck (excluding cervical spine injuries).

The secondary outcome variables were multiple AI, polytrauma, and mortality. Multiple AIs were established for all patients diagnosed with at least two different AIs. Polytrauma was defined as the involvement of at least two different organ systems, and at least one of the injuries being life-threatening. Mortality was registered during hospitalization.

4.4 Predictor variable

The primary predictor variable in Studies I–IV was the age group (i.e. geriatric patients versus younger controls).

4.5 Radiological diagnosis and analyses of facial fractures

For all patients in Studies I and II, radiological trauma diagnosis was based on plain radiography of the lower jaw (panoramic tomography, radiography in Towne projection) and/or computed tomography (CT) of the facial bones. CT imaging was performed using multi-detector CT scanners (GE Healthcare, Milwaukee, WI) with a bone algorithm. The data were reformatted into axial, coronal, and sagittal images with a thickness of 1.0, 1.5, or 2.0 mm. The location of facial fracture(s) in Studies I and II was registered by two authors (M.T. and H.T.).

For all patients in Study III, orbital fractures were diagnosed from CT imaging as described for Studies I and II. CT analyses and measurements were performed independently by two authors (M.T. and S.A.). In the case of disagreement regarding the degree of dislocation or orbital fractured area, the lower measured value was chosen for the analysis. The involvement of relevant intraorbital landmarks was only registered in the case of agreement.

For all patients in Study IV, ZMO fractures were diagnosed from CT imaging as described for Studies I and II. CT analyses and measurements were performed independently by two authors (M.T. and S.A.). In the case of disagreement regarding the degree of ZMO fracture dislocation, the fracture was determined as undislocated only if both authors agreed independently. In the case of disagreement regarding the presence of dislocation, the fracture was determined as dislocated if either of the authors registered the presence of dislocation.

4.6 Statistical analyses

SPSS software was used for statistical analyses in Studies I to IV. Chi-squared tests were performed to examine the statistical significance of the differences between the primary predictors (age) and all the outcome variables. Risk ratios (RRs) with 95% confidence intervals (95% CIs) were calculated to examine the risk of outcome(s). Logistic regression analysis was performed to study the association between the primary predictor and outcome variable(s) and results were expressed as odds ratios (ORs) with 95% confidence intervals (95% CIs). Bivariate associations were further adjusted for variables described in each study, including logistic regression analysis.

4.7 Ethical considerations

The internal review board of the Division of Musculoskeletal Surgery, Helsinki University Hospital, approved Studies I to IV.

5. Results

5.1 Gender, age, and time distribution and causes of facial fractures (Studies I, III, and IV)

Tables 1–3 summarize the age and gender distribution and causes of injuries in patients diagnosed with all types of facial fractures (Study I), in patients diagnosed with isolated unilateral orbital fractures (Study III), and those with isolated unilateral ZMO fractures (Study IV). In all facial trauma cohorts, the proportion of female patients was significantly higher among the geriatric patients (47.3–66.7%) when compared to younger adult patients (10.3–34.5%) ($P < .001$). The cause of injury also significantly differed in all cohorts between the study and control groups ($P < .001$). Falling on the ground was by far the commonest trauma mechanism in all three cohorts among the geriatric patients (64.1–79.2%), whereas assault was the commonest cause in younger controls (48.5–67.2%) ($P < .001$). Intoxication confirmed with a breathalyzer was found significantly more often among the younger controls ($P < .001$); however, the frequency of intoxication in geriatric patients was 11.1% in all types of facial trauma, 11.8% in isolated ZMO, and 15.8% in isolated orbital fractures, which is nevertheless notable.

Table 1. Distribution of age and gender, and causes of injuries in 117 geriatric patients and 136 younger controls (modified from Study I)

	Geriatric patients Number of patients (% of 117)	Younger controls Number of patients (% of 136)	*P*-value**
Age			
Average (yrs)	76.3	34.0	
Range (yrs)	65 - 95	20 - 50	
Gender			< .001
Female	64 (54.7)	25 (18.4)	
Cause of injury			< .001
Fall on the ground	75 (64.1)	17 (12.5)	< .001
MVA	18 (15.4)	13 (9.6)	.159
Hit by a motor vehicle	13	0	< .001
Driver/passenger in a motor vehicle	5	13	.102
Fall from height	6 (5.1)	7 (5.1)	.994
Unknown	6 (5.1)	0 (0.0)	.008
Bicycle accident	5 (4.3)	17 (12.5)	. 021
Assault	5 (4.3)	70 (51.5)	< .001
Hit by a blunt object	1 (0.9)	3 (2.2)	.390
Gunshot accident	1 (0.9)	0 (0.0)	.280
Sports-related accident	0 (0.0)	9 (6.6)	.005
Intoxication*			< .001
Yes	13 (11.1)	47 (34.6)	

Abbreviations: MVA, motor vehicle accident; *confirmed with breathalyzer; ** chi-squared test

Table 2. Distribution of age and gender, and causes of injuries in 72 geriatric patients and 58 younger controls with an isolated unilateral orbital fracture (modified from Study III)

	Geriatric patients Number of patients (% of 72)	Younger controls Number of patients (% of 58)	*P*-value**
Age			
Average (yrs)	77.3	33.4	
Range (yrs)	65-95	20 - 50	
Gender			< .001
Female	48 (66.7)	20 (34.5)	
Cause of injury			< .001
Fall on the ground	57 (79.2)	3 (5.2)	< .001
Unknown	4 (5.6)	1 (1.7)	.259
Assault	3 (4.2)	39 (67.2)	< .001
MVA	3 (4.2)	5 (8.6)	.294
Fall from height	2 (2.8)	3 (5.2)	.480
Bicycle accident	2 (2.8)	3 (5.2)	.480
Hit by a blunt object	1 (1.4)	0 (0.0)	.368
Sports-related accident	0 (0.0)	4 (6.9)	.024
Intoxication*			.003
Yes	11 (15.3)	22 (37.9)	

Abbreviations: MVA, motor vehicle accident; *, confirmed with breathalyzer; **, chi-squared test

Table 3. Distribution of age and gender, and causes of injuries in 93 geriatric patients and 68 younger controls with an isolated unilateral ZMO fracture (modified from Study IV)

	Geriatric patients Number of patients (% of 93)	Younger controls Number of patients (% of 68)	*P*-value**
Age			
Average	76.3	25.8	
Range	65 - 97	20 - 30	
Gender			< .001
Female	44 (47.3)	7 (10.3)	
Cause of injury			< .001
Fall on the ground	65 (69.9)	8 (11.8)	< .001
Bicycle accident	12 (12.9)	7 (10.3)	.612
MVA	6 (6.5	3 (4.4)	.578
Fall from height	5 (5.4)	4 (5.9)	.890
Assault	3 (3.2)	33 (48.5)	< .001
Unknown	1 (1.1)	0 (0.0)	.391
Hit by a blunt object	1 (1.1)	3 (4.4)	.179
Sports-related accident	0 (0.0)	10 (14.7)	< .001
Intoxication*			.081
Yes	11 (11.8)	15 (22.1)	

Abbreviations: ZMO, zygomatico-orbital; MVA, motor vehicle accident; *, confirmed with breathalyzer; **, chi-squared test

Figure 4 shows the accident rates per month and week for the 117 geriatric and 136 younger adult patients (Study I). In relation to the day of the week, 61.7% of the fractures in younger controls occurred from Friday to Sunday, the corresponding rate for the geriatric patients being 42.7% (P = .003). Compared with younger adults, the accident rates were significantly higher in geriatric patients during the autumn and winter months. Of all injuries in geriatric patients, 56.4% occurred between September and February, the corresponding rate among the controls being 43.4% (*P* = .040).

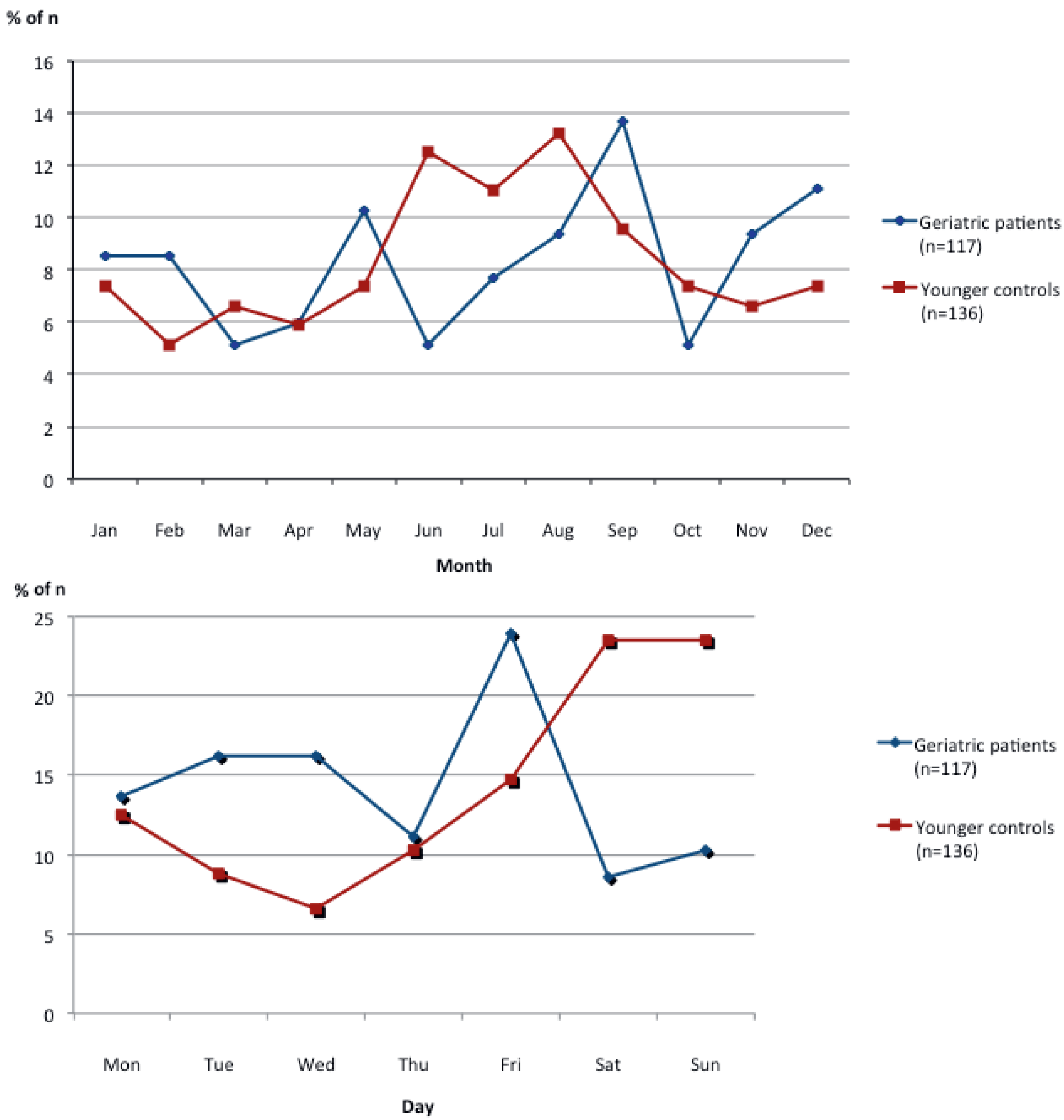


Figure 4: Accident rates per month and week in 117 geriatric and 136 younger adult patients (published in Study I).

5.2 Types and clinical features of facial fractures (Study I, III and IV)

5.2.1 Anatomical distribution of facial fractures (Study I)

Table 4 presents the anatomical distribution of facial fractures in 117 geriatric and 136 younger controls. The study and control groups significantly differed in the location of facial fractures according to the facial third ($P < .001$) and the types of facial fractures ($P = .002$). Regarding the distribution of fractures according to facial thirds in the cranio-caudal direction, injuries in the midfacial region were by far more common in the elderly (74.7%) than younger controls (55.1%) ($P = .001$). Of the fracture types, isolated ZMO fractures were the commonest type of injury in the elderly (29.9%), followed closely by isolated orbital fractures (21.4%). While isolated orbital fractures were significantly more common among the elderly than the controls ($P = .015$), isolated mandibular fractures were more frequent in the younger adults ($P < .001$).

Table 4. Anatomical distribution of facial fractures in 117 geriatric patients and 136 younger controls (modified from Study I)

	Geriatric patients Number of patients (% of 117)	Younger controls Number of patients (% of 136)	*P*-value**
Location of facial fracture by facial third			.001
Isolated middle facial third	87 (74.4)	75 (55.1)	.001
Isolated lower facial third	16 (13.7)	48 (35.3)	< .001
Isolated upper facial third	12 (10.3)	10 (7.4)	.414
Combined	2 (1.7)	3 (2.2)	.521
Type of facial fracture			.002
Isolated ZMO	35 (29.9)	40 (29.4)	.930
Isolated orbital	25 (21.4)	14 (10.3)	.015
Isolated mandibular	16 (13.7)	48 (35.3)	< .001
Isolated nasal	15 (12.8)	10 (7.4)	.146
Combined	12 (10.3)	10 (7.4)	.414
Other*	14 (12.0)	14 (10.3)	.673

Abbreviations: ZMO, zygomatico-orbital; MVA, motor vehicle accident; *, extensive midfacial, isolated wall of the maxillary sinus, isolated upper third, isolated dentoalveolar; **, chi-squared test

5.2.2 Characteristics of isolated unilateral orbital fractures (Study III)

Table 5 summarizes the characteristics of isolated unilateral orbital fractures in 72 geriatric patients and 58 younger controls. In the geriatric patients, isolated fractures of the orbital floor were the most common fracture type (66.7 %). The difference between the groups was statistically significant in relation to the associated zone (*P* = .032) and fractured area (*P* = .045). Fractures were frequently extensive (≥2 cm^2) among the elderly (43.1%) and associated with the middle and posterior parts of the orbit in the majority (63.9%) of cases. Severe ocular injuries, such as retrobulbar hematoma (RBH), retinal rupture or detachment, and lens luxation, were exclusively observed in the geriatric group (5.6%).

Table 5. Characteristics of 72 geriatric patients and 58 younger controls diagnosed with an isolated unilateral orbital fracture (modified from Study III)

	Geriatric patients Number of patients (% of 72)	Younger controls Number of patients (% of 58)	*P*-value¥
Type of orbital fracture			.253
Isolated floor	48 (66.7)	36 (62.1)	.586
Combined*	15 (20.8)	11 (19.0)	.791
Isolated medial	5 (6.9)	9 (15.5)	.117
Other**	4 (5.6)	2 (3.4)	.569
Associated orbital zone			.032
Zone 2–3, 1–3, or 3	46 (63.9)	27 (46.6)	.048
Zone 1, 2, or 1–2	26 (36.1)	31 (53.4)	.048
Fractured area			.045
≥2 cm^2	31 (43.1)	18 (31.0)	.160
<2 cm^2 (non-fissure)	23 (31.9)	31 (53.5)	.013
Fissural	18 (25.0)	9 (15.5)	.185
Severe ocular injury			.068
Yes	4 (5.6)	0 (0.0)	.068
Retrobulbar hematoma	2 (1.8)	0 (0.0)	.201
Retinal rupture/detachment	1 (1.4)	0 (0.0)	.368
Lens luxation	1 (1.4)	0 (0.0)	.368
Primary altered ocular position			.437
Yes	15 (20.8)	9 (15.5)	.437
Enophthalmos	9 (12.5)	8 (13.8)	.828
Exophthalmos	6 (8.3)	1 (1.7)	.987
Posttraumatic binocular diplopia			.605
Yes	15 (20.8%)	10 (17.2)	

Abbreviations: *, combined fracture of the floor + medial or lateral wall, medial + lateral wall, floor + medial wall + roof; **, isolated fracture of the orbita roof or lateral wall; ¥, chi-squared test

Table 6 presents the results of logistic regression analysis with 95% confidential intervals between the types of isolated orbital fractures, the associated zones, fracture area, and the study groups. Geriatric patients had a significantly elevated, 2.2-fold higher risk of orbital fractures affecting the middle and posterior parts of the orbital wall (zones 1–3, 2–3, or 3) when compared to younger adult patients (*P* = .033). The risk of extensive (≥2 cm^2) orbital fractures was 2.3-fold higher among the elderly when compared to younger adults with ≤2 cm^2 (*P* = .037). However, the difference did not remain statistically significant when adjusted.

Table 6. Logistic regression analyses between types of orbital fracture, the associated zones, fractured area, and age group in 72 geriatric and 58 younger controls diagnosed with an isolated unilateral orbital fracture (published in Study III)

	Orbital Fracture Type (Isolated floor)	Associated zone Zone 1–3, 2–3, or 3	Fracture area	
			≥2 cm^2 (A)	≥2 cm^2 (B)
Unadjusted				
Geriatric patients	1.2 (0.6–2.5)	2.2 (1.1–4.4)	1.6 (0.8–3.5)	2.3 (1.1–5.1)
Younger controls	REF	REF	REF	REF
P-value	.586	.033	.161	.037
Adjusted*				
Geriatric patients	1.5 (0.5–4.9)	3.2 (0.9–11.8)	1.7 (0.5–6.6)	2.7 (0.6–12.3)
Younger controls	REF	REF	REF	REF
P-value	.506	.082	.415	.198

Data presented as odds ratios (95% confidence intervals). Abbreviations: A, comparison with fissures and ≤2 cm^2 fractures (n = 130); B, comparison with ≤2 cm^2 fractures (n = 103); *, Adjusted for sex, trauma mechanism, alcohol, and fracture type (except for type of orbital fracture); ref, reference

5.2.3 Characteristics of isolated unilateral ZMO fractures (Study IV)

Table 7 presents the characteristics of isolated unilateral ZMO fractures in 93 geriatric and 68 younger adult patients. Among the elderly, ZMO fractures including the arch were the commonest type of injury (69.9%). In geriatric patients, ZMO fracture dislocation was present in the majority (68.8%). However, despite the high frequency of fracture dislocation in the elderly, the great majority did not show any restriction of mandibular opening (84.9%) and the majority did not have clinical asymmetry of the zygomatic prominence (55.9%) as compared to the contralateral side. The comparison of geriatric patients with younger controls revealed that ZMO fractures were significantly more often undislocated ($P = .004$), the maximal mandibular opening was more frequently unrestricted ($P = .001$), and asymmetry of the zygomatic prominence was absent more often in the elderly ($P < .001$).

Table 7. Characteristics of 93 geriatric patients and 68 younger controls diagnosed with an unilateral ZMO fracture (modified from Study IV)

	Geriatric patients Number of patients (% of 93)	Younger controls Number of patients (% of 68)	*P*-value*
Type of ZMO fracture			.884
ZMO with arch fracture	65 (69.9)	46 (67.7)	.761
Isolated arch fracture	15 (16.1)	13 (19.1)	.621
ZMO without arch fracture	13 (14.0)	9 (13.2)	.892
ZMO dislocation			.004
Present	64 (68.8)	61 (89.7)	.002
Absent	29 (31.2)	7 (10.3)	.002
Restricted maximal mandible opening			< .001
No restriction	79 (84.9)	43 (63.2)	.001
Restricted	9 (9.7)	23 (33.8)	< .001
Inconclusive	5 (5.4)	2 (2.9)	.454
Asymmetry of the zygomatic prominence			< .001
No	52 (55.9)	8 (11.8)	< .001
Yes	31 (33.3)	44 (64.7)	< .001
Inconclusive	10 (10.8)	16 (23.5)	.030

Abbreviations: ZMO, zygomatico-orbital; *, chi-squared test

5.3 Associated injuries outside the facial region (Studies II and IV)

5.3.1 Associated injuries in patients with different types of facial fractures (Study II)

Table 8 summarizes the occurrence, types, and severity of AI in 117 geriatric patients and 136 younger controls with different types of facial fractures. AIs in general were significantly more frequent in geriatric patients (44.4%) than in younger controls (25.0%) ($P < .001$). The commonest AIs in geriatric patients were limb (29.9%) and brain (18.8%) injuries. As compared to younger adults, geriatric patients more frequently had associated limb ($P = .005$) and spinal ($P = .041$) injuries. Geriatric patients were diagnosed more often with multiple AIs ($P = .003$) and polytrauma ($P = .039$). Mortality was significantly more frequent in the elderly group than in the younger controls ($P = .008$).

Table 8. Occurence, types and severities of AI in 117 geriatric patients and 136 younger controls with different types of facial fractures (published in Study II)

	Geriatric patients Number of patients (% of 117)	Younger controls Number of patients (% of 136)	*P*-value*
AIs present			< .001
Yes	52 (44.4%)	34 (25.0)	
Affected organ system			.545
Limb	32 (27.4)	18 (13.2)	.005
Brain	22 (18.8)	17 (12.5)	.166
Chest	13 (11.1)	8 (5.9)	.133
Spine	9 (7.7)	3 (2.2)	.041
Abdomen	0 (0.0)	1 (0.7)	.353
Severity of AI			< .001
Multiple AIs	25 (21.4)	11 (8.1)	.003
Polytrauma	17 (14.5)	9 (6.6)	.039
Mortality	6 (5.1)	0 (0.0)	.008

Abbreviations: AI, associated injury; *, chi-squared test

Table 9 displays the association between the cause of injury, type of facial fracture, and presence of AIs in 117 geriatric patients and 136 younger adults diagnosed with all types of facial fractures. The significant predictors for AIs were MVAs and falling from height ($P < .001$). AIs associated significantly more often with combined facial fractures ($P = .033$) and isolated fractures of the maxillary sinus wall ($P < .001$).

Table 9. The association between cause of injury, type of facial fracture, and presence of AI in 117 geriatric and 136 younger controls (modified from Study II)

	AI Present Patients, n (%)	AI Absent Patients, n (%)	*P*-value*
Population	86 (34.0)	167 (66.0)	
Trauma mechanism			< .001
Fall on the ground	24 (26.1)	68 (73.9)	.045
MVA	27 (87.1)	4 (12.9)	<.001
Fall from height	10 (76.9)	3 (23.1)	<.001
Unknown	5 (83.3)	1 (16.7)	.010
Bicycle accident	7 (31.8)	15 (68.2)	.822
Assault	10 (13.3)	65 (86.7)	<.001
Gunshot accident	0 (0.0)	1 (100.0)	.472
Hit by a blunt object	2 (50.0)	2 (50.0)	.450
Sport	1 (11.1)	8 (88.9)	.140
Type of facial fracture			< .001
Isolated zygomatico-orbital	23 (37.3)	47 (62.7)	.466
Isolated orbital	13 (33.3)	26 (66.7)	.925
Isolated mandibular	8 (12.5)	56 (87.5)	<.001
Isolated nasal	9 (36.0)	16 (64.0)	.823
Combined	12 (57.1)	9 (42.9)	.033
Extensive midfacial	6 (37.5)	10 (62.5)	.613
Isolated wall of maxillary sinus	7 (100.0)	0 (0.0)	<.001
Isolated upper third	3 (60.0)	2 (40.0)	.215
Isolated dentoalveolar	0 (0.0)	1 (100.0)	.472

Abbreviations: AI, associated injury; MVA, motor vehicle accident, *, chi-squared test

Table 10 presents the risk analysis between the presence of AIs, multiple AIs, polytrauma, limb injury, and age group. In 2 x 2 risk analysis, the geriatric patients had a 1.8-fold higher risk of AIs (*P* = .002), a 2.6-fold higher risk of multiple AIs (*P* = .004), and a 2.1-fold higher risk of limb injury (*P* = .006) when compared to the younger adult patients.

Table 10. The association between cause of injury, type of facial fracture, and presence of AI in 117 geriatric and 136 younger controls (modified from Study II)

	AI present	Multiple AIs	Polytrauma	Limb injury
Geriatric group	1.8 (1.2–2.5)	2.6 (1.4 –5.1)	2.2 (1.0–4.7)	2.1 (1.2–3.5)
Younger control	ref	ref	ref	ref
P-value	.002	.004	.050	.006

Data presented as risk ratios (95% confidence intervals).
Abbreviations: AI, associated injury; ref, reference

5.3.2 Associated injuries in patients with isolated unilateral ZMO fractures (Study IV)

Table 11 summarizes the occurrence and types of AI in 93 geriatric and 68 younger adult patients diagnosed with an isolated unilateral ZMO fracture. AIs occurred in 43.0% of geriatric patients, brain (25.8%) and limb (20.4%) injuries being the most common. Compared to younger adults, AIs in general (*P* < .001) and brain injuries in particular (*P* < .001) occurred significantly more often.

Table 11. Occurence and types of AI in 93 geriatric patients and 68 younger controls with an isolated unilateral ZMO fracture (modified from Study IV)

	Geriatric patients Number of patients (% of 93)	Younger controls Number of patients (% of 68)	*P*-value*
AI present			< .001
Yes	40 (43.0)	10 (14.7)	
Type of AI			< .001
Brain	24 (25.8)	3 (4.4)	< .001
Limb	19 (20.4)	9 (13.2)	.234
Chest	5 (5.4)	5 (7.4)	.608
Spine	4 (4.3)	1 (1.5)	.307
Abdomen	2 (2.2)	0	.224
Carotid artery dissection	0	1 (1.5)	.241

Abbreviations: ZMO, zygomatico-orbital; *, chi-squared test

Table 12 presents the risk analysis with 2 x 2 tables between the absence of fracture dislocation, presence of AI, brain injury, multiple AIs, polytrauma, ocular injury, and age group. Geriatric patients had a 3.4-fold higher risk of undislocated fractures when compared to younger adults ($P = .003$). Moreover, the elderly had a 2.9-fold higher risk of AIs ($P < .001$) and a 5.8-fold higher risk of brain injury ($P = .003$) when compared to younger adult patients.

Table 12. Risk analysis between the absence of fracture dislocation, presence and severity of AI, presence of brain injury and ocular injury, and age group in 93 geriatric and 68 younger controls with an isolated unilateral ZMO fracture (published in Study IV)

	Dislocation absent	AIs present	Brain injury	Multiple AIs	Polytrauma	Ocular injury
Geriatric patients	3.4 (1.4-8.0)	2.9 (1.6-5.4)	5.8 (1.8-8.6)	2.9 (0.6-13.3)	1.1 (0.2-6.4)	2.9 (0.3-25.6)
Younger controls	ref	ref	ref	ref	ref	ref
P-value	.003	< .001	.003	.166	.918	.332

Data presented as risk ratios (95% confidence intervals).
Abbreviations: AI, associated injury ; ref, reference

Table 13 summarizes the logistic regression analysis for the presence of brain injury in 93 geriatric patients and 68 younger controls diagnosed with an isolated unilateral ZMO fracture. Geriatric patients had a significant, 7.5-fold higher risk of brain injury ($P = .002$), and the risk remained 5.3-fold higher when compared to younger controls and adjusted for gender, trauma mechanism, and the presence of dislocation ($P = .012$). In logistic regression analysis, the absence of fracture dislocation resulted in a 2.5-fold and statistically significantly higher risk of the presence of brain injury when compared to the presence of dislocation and adjusted ($P = .046$).

Table 13. Logistic regression analysis with 95% confidence intervals for the presence of brain injury in 93 geriatric and 68 younger controls with an isolated unilateral ZMO fracture (published in Study IV)

	Unadjusted			Adjusted*		
	OR	95 % CI	*P*-value	OR	95 % CI	*P*-value
Age group						
Geriatric patients	7.5	2.2–26.2	.002	5.3	1.4–19.7	.012
Younger controls	ref.					
Gender						
Female	2.8	1.2–6.6	.016	1.6	0.7–4.0	.300
Male	–	–	–	ref.		
Dislocation						
Absent	3.5	1.5–8.4	< .001	2.5	1.0 – 6.3	.046
Present	–	–	–	ref.		

Abbreviations: ZMO, zygomatico-orbital; CI, confidence interval; OR, odds ratio; *, adjusted for age, gender, and dislocation; ref, reference

6. Discussion

The aims of the present study were to investigate facial fractures and associated injuries in geriatric patients, and to clarify whether they differ from those in younger adults. We hypothesized that the causes and types of facial fractures in geriatric patients differ from those in younger adults, and that associated injuries are more frequent and severe in geriatric patients.

6.1 Methodological considerations

The presented outcome variables were analyzed retrospectively in 117 geriatric and 136 younger adult patients in Studies I and II. In Study III, the study population comprised 72 geriatric and 58 younger controls, and in Study IV, 93 geriatric and 68 younger adult patients. The patient groups were determined to be sufficiently large for a comparison of groups and appropriate for finding statistical differences between the groups.

The drawback of the present study was its retrospective nature. For instance, it can be questioned whether the rate of intoxication would have been even greater if the measurement had been carried out under prospective study conditions, when compared to the reported incidence, which in the present study was based on breathalyzer measurements conducted for medical treatment purposes. The mortality rates registered are probably underestimated, as some patients were referred to another hospital for recovery after the initial trauma intervention and follow-up. Clarification of the reason for death would have been interesting, but was far too challenging due to the retrospective nature of the study. For this same reason, trauma severity scores such as TRISS could not be used, which would have been beneficial. However, the severity of AIs was classified into multiple AIs or polytrauma, which the author considers meaningful enough for the purposes of this study. In relation to traumatic brain injuries, the study only included those intracranial injuries that had been confirmed with radiological imaging. In a prospective study, the registration of mild brain injuries only diagnosed from clinical symptoms would have been possible. In relation to the extensiveness of orbital fractures, a follow-up of non-operative orbital fractures would have yielded significant information on the long-term effects of these injuries.

The strengths of the present study are that it was able to present the confounding differences in the causes of and resulting types of facial trauma between geriatric and younger adult patients. The study revealed that conventional clinical parameters may not be sufficient for the evaluation of orbital fractures in geriatric patients after injury. In relation to AIs, the present study was able to show the severity and related mortality, which are of high priority in trauma care. In relation to different types of AIs, the present study was able to demonstrate a relationship between brain trauma and ZMO fractures in geriatric patients. This finding is important, as ZMO fractures are generally considered as lower energy trauma mechanisms and non-severe facial injuries.

6.2 Causes of facial fractures and aging

The causes of facial fractures are age dependent. Small children sustain facial injuries due to falling (15.4–44.3%) and bicycle accidents (15.2–27.8%), whereas interpersonal violence starts to rise its ugly head among teenagers (13.3–23.5%) (Thorén, Iso-Kungas et al. 2009, Zhou, Ongodia et al. 2013), reaching its highest frequency among younger adult patients (39.0–42.0%) (Kontio, Suuronen et al. 2005, Boffano, Roccia et al. 2015).

In Finnish populations, assault was identified as the commonest cause of facial trauma in younger adults from the 1980s (42.0%) to the 1990s (42.0%) (Kontio, Suuronen et al. 2005). Although Kontio et at al. did not examine the relationship between facial trauma and age, it is notable that younger adult patients aged 20 to 50 years comprised 68% of facial trauma patients in both cohorts and that elderly patients (aged at least 61 years) comprised only 3.8–5.9% of the populations reported (Kontio, Suuronen et al. 2005). When comparing the results of the present study with those presented by Kontio et al., the frequency of interpersonal violence was even higher in the present study among the younger adult patients (48.5–67.2%). With increasing age, the cause of facial of fractures further changes, falling on the ground becoming the commonest cause of geriatric facial trauma (55.9–86.6%) (Gerbino, Roccia et al. 1999, Imholz, Combescure et al. 2014). The results of the present study confirmed the findings of the studies mentioned above, as the frequency of falling varied from 64.1% to 79.2% among geriatric patients. In addition to different types of facial injuries in the elderly, the relative rate of falling was even higher in cohorts of patients diagnosed with isolated ZMO (69.9 %) and orbital (79.2 %) fractures than among elderly individuals diagnosed with all types of facial trauma (64.1%).

Although the present study demonstrated an association between falling and facial fractures in the elderly, the question of causality arises. Physiologically, an attempt is made to prevent falling through reflexes with posture correction and, for example, with outstretched upper extremities. The literature has shown that the ability to oppose the falling energy with the upper extremities can be compromised with rising age. In a study by Sran et al., upper extremity muscle strength among elderly females aged at least 65 years was revealed to be up to 45% lower than that of robust females under 65 years old (Sran, Stotz et al. 2010). In addition to the potential deterioration of reflexes, the reduction of upper limb muscle strength, particularly in elderly females, can be among the mechanistic factors explaining why falling-related energy is directed to the facial region.

6.2.1 Alcohol and season of the year in geriatric facial trauma

Several studies have demonstrated the commonness of alcohol consumption and abuse among geriatric patients. Roughly one fifth of Finnish senior citizens consume alcohol on a daily basis according to the results of questionnaire studies in which patients have anonymously evaluated and reported their alcohol usage. The commonest reported reasons for alcohol usage have been for medical purposes (e.g. cardiovascular diseases, sleep disorders, mental disorders), common colds, and indigestion. (Aira, Hartikainen et al. 2008, Immonen, Valvanne et al. 2011a, Immonen, Valvanne et al. 2011b)

Although the consumption of alcohol reported in questionnaires has usually been low, it has nevertheless been associated with worry among relatives, and also with falls and fractures (Immonen, Valvanne et al. 2011a). Even low dose usage of alcohol should not be underestimated in the elderly when taking account that the tolerance of alcohol diminishes with rising age, and that according to the Finnish recommendations, the limits for moderate and high-risk alcohol usage in the elderly are a half to a quarter of the respective limits for younger females and males (Treatment of alcohol abuse: Current Care Guidelines Abstract 2015). In the results of the present study (Studies I, III, and IV), alcohol abuse was significantly more frequent among the younger controls. However, the rate of breathalyzer-confirmed intoxication of 11.1–15.3% during facial fracture diagnosis in geriatric patients is nevertheless notable when considering the risk of falling.

In relation to the external risk factors of falling, the orthopedic trauma literature has clearly shown that geriatric patients are more prone to sustaining fractures of the hip and upper extremities, while ankle injuries occur more frequently during the cold and slippery winter seasons (Lin, Xiraxagar 2006, Bischoff-Ferrari, Orav et al. 2007). As the present study results revealed, there is an association between the season and frequency of facial fractures among geriatric patients, with the elderly being more prone to sustaining facial fractures from late fall until early spring than younger adult patients. During the slippery seasons, preventive measures such as grip devices on shoes can also be recommended in the prevention of facial trauma.

6.3 Site of facial fracture and aging

As stated for the causes of facial injury, the resulting type of facial fracture is also age dependent. A multi-center study of European patients (mean age from 29.9 to 43.9 years) published in 2015 identified fractures of mandible (42.0%) as the commonest type of injury, followed by ZMO (24.0%) and orbital (16.0%) fractures (Boffano, Roccia et al. 2015).

A corresponding result was found for the younger controls in present study, with isolated mandibular fractures being the commonest type of injury (35.3 %), followed by isolated ZMO (29.4%) and orbital (10.3%) fractures. On the contrary, isolated midfacial fractures were by far the commonest type of injury among geriatric patients, comprising up to 74.4% of all facial injuries in this patient group. This frequency is consistent with previous publications focusing on geriatric facial trauma (41.0–84.9%) (Royan, Hamid et al. 2008, Kloss, Tuli, Hächl et al. 2007, Martinez, Como et al. 2014). In the results of the present study, among geriatric patients diagnosed with all types of facial fractures, isolated ZMO (29.9%) and orbital (21.4%) fractures were the commonest injury types.

In the recent literature focusing on geriatric facial trauma, the highest frequencies of midfacial fractures in geriatric patients have been presented by Martinez et al., who also compared younger adult patients with geriatric patients, but in cohorts from two different time periods. More specifically, they observed that the rate of midfacial fractures rose dramatically among geriatric patients from the 1990s (n = 1 fracture diagnosed) to the 2010s (n = 251 fractures diagnosed) (Martinez, Como et al. 2014). Such a major difference raises concern over potential underdiagnosis in geriatric facial trauma in previous decades. This potential underdiagnosis could be explained by challenges in the interpretation of plain X-rays of facial bones. This should no longer be a problem due to the generalization of computed tomography (CT), and facial CT becoming the golden standard and recommended method of examination, particularly in the diagnosis of midfacial trauma, in the 20th century (Miloro, Larsen et al. 2004).

In addition to advanced diagnostic tools, another explanatory factor for the higher frequency of midfacial fractures in geriatric patients could be changes in bone quality and density, particularly in patients diagnosed with osteoporosis. A prospective case–control study presented by Lee et al. compared the density of facial bones in Hounsfield Units (HU) from facial bone CTs between a cohort of 47 patients diagnosed with osteoporosis (-2.5 SD for the *T*-score of L2-4 in DEXA scans) with a group of 49 patients without osteoporosis (0.22 SD for the *T*-score of L2-4 in DEXA scans). The central finding of Lee et al. was the detected lower density of midfacial bones, particularly in the orbital floor, in those patients diagnosed with osteoporosis when compared to patients without osteoporosis. (Lee, Lee et al. 2013)

Previous research has shown that the frequency of facial fractures is correlated with a rising degree of osteopenia (Werning, Downey et al. 2004). However, the preciseness and reliability of bone density evaluation based on the HU value can be questioned due to the dependence on the imaging protocol and setup, and also the location of individual measurement points. Despite the potential elements of uncertainty, decreased bone density in elderly patients with diagnosed osteopenia or osteoporosis could be one of the explanatory factors for the higher frequency of midfacial fractures.

6.3.1 Severity of orbital trauma in geriatric patients

An orbital fracture can lead to functional impairment and vision-threatening complications, such as diplopia and intraorbital hemorrhages, and associate with different types of ocular injuries such as lens luxation, retinal hemorrhages, or detachment of the retinae (Ellis 2012, Zhang, Zhang et al. 2012, He, Blomquist et al. 2007, Cook 2002, Brown, Rix et al. 2016). Binocular post-traumatic diplopia, or the prevention of it, has been accepted as the main indication for surgical repair in orbital fracture (Ellis 2012, Zhang, Zhang et al. 2012). However, other factors such as post-traumatic swelling and ocular injuries such as lens luxation also affect this clinical parameter when estimating the clinical relevance of an orbital fracture.

The fractures behind the globe equatorial, i.e. in the middle and the posterior part of the orbital, wall have been shown to relate to a changed ocular position (Zhang, Zhang et al. 2012). In the results of Study III, the orbital fractures were significantly more often extensive and affected the middle and posterior part of the orbital wall among the geriatric patients than the younger controls. However, binocular diplopia and GMP were not more frequent among the elderly; instead, post-traumatic exophthalmos was more frequent among the elderly than the controls. Although immediate post-traumatic GMP (e.g. hypoglobus or enophthalmos) has traditionally been accepted as an indicator of surgical repair, based on the present study results, GMP cannot be used as a reliable indicator, particularly in the elderly population.

When comparing the nature of an orbital fracture, significant differences can be found between ages groups. In small children, bone elasticity allows the orbital wall to dislocate and relocate in orbital trauma, resulting in the dreaded trapdoor fracture, threatening vision and potentially hemodynamics (Ellis 2012). This injury is very rarely seen in adult patients. When compared to the most central finding of the present study (Study III), orbital fractures were significantly more often extensive among elderly than younger adult patients. As discussed above, diminished bone density can be one of the explanatory factors (Lee, Lee et al. 2013). However, according to the orthopedic literature, cortical bone porosity increases, whereas periosteal apposition decreases as a function of rising age (Zebaze, Ghasem-Zadeh et al. 2010, Szulc, Seeman et al. 2006).

When comparing the literature and present findings, age has a considerable influence on the nature of orbital trauma, and it can be emphasized that decreased midfacial bone density, cortical bone porosity, and additionally the age-related changes in periosteal support and tissue flexibility, explain the extensiveness of orbital fractures in the elderly.

6.4 AIs in Facial Fractures and Severity of Injuries

Facial fracture patients are a heterogeneous group whose facial injuries vary from soft tissue injuries needing minor intervention to panfacial fractures requiring challenging reconstructions and prolonged hospitalization. Within the scope of this thesis, AIs are defined as any major injury outside the facial region, although the term associated or concomitant injury in facial trauma has also been used, for example, with associated dental and ocular injuries (Thorén, Snäll et al. 2010, Beogo, Dakoure et al. 2013, Scherbaum Eidt, De Conto et al. 2013, Kloss, Tuli et al. 2007, Imholz, Combescure et al. 2014, Shumate, Portnof et al. 2018).

The frequency of AIs outside the face in facial trauma patients of all ages has varied from 18.2% to 25.2% in publications where minor injuries such as soft tissue wounds, bruises, and brain concussions have been excluded (Thorén, Snäll et al. 2010, Beogo, Dakoure et al. 2013). If these types of minor injuries are included, the rate rises to 30.8–35.3% among patients of all ages diagnosed with facial fractures (Allareddy, Allareddy et al. 2011, Scherbaum Eidt, De Conto et al. 2013).

In the results of the present study (Studies II and IV), AIs in general were registered significantly more often in geriatric (43.0–44.4%) than younger adult patients (14.7–25.0%). The results also demonstrated (Study II) that geriatric patients have a significantly higher risk of AIs in general, multiple AI, polytrauma, and mortality when compared to younger controls. More specifically, geriatric patients had a 1.8-fold higher risk of AIs in general, a 2.6-fold higher risk of multiple AIs, and a 2.2-fold higher risk of polytrauma. In patients diagnosed with all types of facial injuries (Study II), the significant predictors for the presence of AI were MVAs and falls from height. Notably, however, 26.1% of AIs were registered in relation to low-level falls in geriatric patients (Study II). Besides the severity of facial fractures, AIs outside the face are the factors having a major influence on the length of hospitalization, the need for intensive care, and post-traumatic recovery (Imholz, Combescure et al. 2014).

The present study underlines the severity of geriatric falls and facial trauma. Although the physical resources and the level of frailty were not recorded in the present study, underlying frailty could be one of the explanatory factors predisposing the elderly to more severe injuries and prolonged rehabilitation (Orouji Jokar, Ibraheem et al. 2016, McIsaac, Moloo et al. 2017).

6.4.1 Different types of AIs in geriatric facial trauma patients

In publications focusing on the severity of geriatric facial trauma, the frequency of AIs has varied from 40% to 48% (Kloss, Tuli et al. 2007, Imholz, Combescure et al. 2014, Shumate, Portnof et al. 2018) if it is assumed that in the publication of Kloss et al., every elderly patient had at least one AI. Within the limitations of this assumption, significant differences can be found between the results of present study and those presented by Kloss et al. and Shumate et al. The frequencies of limb (27.4 vs. 3.9–12.9%), chest (11.1 vs. 1.9–5.7%), and spine (7.7% vs. 1.7–5.9%) injuries were clearly higher in present study than in the studies abovementioned. The frequency of TBI was lower in geriatric patients in studies II and IV (18.8–25.8%), when compared to the frequencies reported by Shumate and Kloss (29.5–35.8%) (Shumate, Portnof et al. 2018, Kloss, Tuli et al. 2007).

The proposed reasons for the differences between the present study and earlier-described studies are related to differences in the inclusion criteria. First, Kloss et al. also included minor injuries such as brain concussions, which were not among the inclusion criteria in the present study. Secondly, Kloss et al. included less severe facial injuries such as dental and soft tissue injuries (Kloss, Tuli et al. 2007), which was not the case in the present study. Thirdly, Shumate et al. included patients aged 75 years or older, while the geriatric patients included in the present study were aged 65 years and older (Shumate, Portnof et al. 2018). In relation to the age distribution, it should be noted that the rate of intracranial injuries rises even after the age of 74 years (Clavijo-Alvarez, Deleyiannis et al. 2012, Kloss, Tuli et al. 2007). Despite the differences, the relevant and similar result of previous publications and the present study is that AIs are much more frequent among geriatric patients than younger controls (Clavijo-Alvarez, Deleyiannis et al. 2012, Imholz, Combescure et al. 2014).

Limb injuries are among the commonest injury types in different types of geriatric falls, the frequency of upper limb injuries varying from 12.0–15.0%, and that of lower limb injuries from 29.0% up to 60.9% (Brown, Rix et al. 2016, Hefny, Abbas et al. 2016, Tripathy, Jagnoor et al. 2015). Limb injuries (27.4%) were the commonest types of injuries registered in geriatric patients diagnosed with all types of facial trauma (Study II). Limb injuries are particularly severe in geriatric patients, as presented by Brown et al., who reported that lower limb injuries with AIS ≥ 3 were three times more frequent in geriatric than non-geriatric patients, and that lower limb injuries caused a 2.0-fold higher independent risk of mortality (Brown, Rix et al. 2016). In geriatric limb injuries, it should also be noted that a combination of two injuries, such as a hip fracture with an upper limb fracture, significantly more often results in exacerbated recovery when compared to these injuries occurring alone (Biber, Grüninger et al. 2017, Thayer, Kleweno et al. 2018).

The frequency of traumatic spinal injuries has varied from 1.7% to 16.9% in facial trauma patients (Thorén, Snäll et al. 2010, Fischer, Zhang et al. 2001, Hackl, Hausberger et al. 2001, Mukherjee, Abhinav et al. 2015). Fisher et al. focused on high-energy trauma mechanisms (i.e. MVAs) and reported the higher end of frequencies (16.9%), with injuries being most common in the cervical spine area (14.9%) (Fischer, Zhang et al. 2001). Hack et al. found a clearly lower rate of spinal injuries (6.7%), but observed that elderly patients in particular were more prone to sustaining spinal injuries with facial fracture(s) (Hackl, Hausberger et al. 2001). Based on the literature and present findings, spinal injuries should actively be excluded in geriatric facial traumas.

6.4.2 Brain injuries in geriatric patients diagnosed with facial fractures

TBIs associated with facial trauma have particularly been related to high-energy facial injuries, such as Le Fort fractures, complex midfacial, and panfacial fractures (Bellamy, Mundinger et al. 2013, Alvi, Doherty et al. 2003). It is notable, however, that particularly among geriatric patients aged at least 65 years, up to 80% of TBIs are sustained due to lower-energy mechanisms, such as ground level falls (Harvey, Close 2012).

Regarding to the type of facial fractures, the literature has shown that TBIs occur in midfacial injuries such as ZMO, nasal, and orbital fractures (Hohlrieder, Hinterhoelzl et al. 2004, Lee, H., Kim et al. 2018), even though these are often considered as lower-energy facial injuries. A study by Lee et al. revealed that 6% of orbital fracture patients without TBI symptoms (e.g. loss of consciousness, intoxication, or nausea/vomiting) had a TBI, and that the risk for the presence of a symptomatic or symptomless TBI in the presence of an orbital roof fracture was 4.15-fold higher when compared to the absence of TBI (Lee, Kim et al. 2018). Hohlrieder et al. demonstrated that the risk of TBI was 1.9-fold higher in ZMO and nasal fractures (Hohlrieder, Hinterhoelzl et al. 2004). Moreover, other publications have reported brain injury frequencies of up to 61–67% in patients diagnosed with ZMO fractures (Patil, Patil et al. 2016, Ramneesh, Gulzar et al. 2014).

In the present study, brain injuries were detected in 18.8% of elderly patients diagnosed with all types of facial fractures (Study II), and in 25.8% of those diagnosed with an isolated ZMO fracture (Study IV). This was notably different from younger adult patients, in whom the corresponding rates were 12.5% (Study II) and 4.4% (Study IV), respectively. Clavijo-Alvarez et al. also reported an association between age and the frequency of brain injuries. In their study, brain injuries were diagnosed in 0.4% of patients aged under 45 years, in 11.7% of patients aged 64–74 years, in 13.7% of patients aged 76–84 years, and in 14.7% of patients aged 85 years or older (Clavijo-Alvarez, Deleyiannis et al. 2012).

The Australian 13-year follow-up study by Harvey et al. revealed that the rate of both concussive and hemorrhagic TBIs rose in patients aged 65 years or older, and that the rate of SDHs and SAHs, in particular, rose from approximately 20% to 70% within the follow-up period (Harvey, Close 2012). The increased usage of anticoagulants (coumadin) was reported as an explanatory factor for mortality by Rogers et al., who conducted an ACT Alert (Anticoagulation and Trauma) protocol to screen the intracranial bleeding process in head traumas among patients using anticoagulants and primarily with a lowered GSC of 13 or less (Rogers, Rogers et al. 2012). Rogers et al. reported improved outcome parameters in patients under the ACT Alert protocol than among the control group, which did not go through the protocol (Rittenhouse, Rogers et al. 2015). However, with aging, age-related brain atrophy takes place, with a combination of increased stiffness of dura attachment inside the neurocranium, predisposing to venous tear under a sudden head impact (Winn 2011). In addition to anticoagulation and antithrombotic therapy, notable factors also include age-related intracranial changes particularly predisposing the elderly to SDHs (Rittenhouse, Rogers et al. 2015, Winn 2011).

Although physiological changes and anticoagulation therapy have a crucial role in the risk of traumatic brain injuries, the association between ZMO fractures and brain trauma is a central finding of the present study that has not previously been reported. Brain injuries need to be meticulously excluded, particularly in geriatric patients diagnosed with lower-energy midfacial injuries such as isolated ZMO fractures.

6.4.3 Severity of brain injury in geriatric patients diagnosed with midfacial fractures

Several classification systems, such as ISS, AIS and TRISS, have been developed for use in general traumatology to enable the estimation of trauma severity. Within the facial region, the facial fracture severity has also been modeled, for instance, by Bagheri et al., who developed a Facial Injury Severity Score (FISS) (Bagheri, Dierks et al. 2006).

The FISS grades facial fractures on a scale from 1 to 6 points per site of facial fracture, particularly emphasizing the higher-energy facial traumas such as Le Fort III (6 points) and panfacial fractures (summation of solitary fractures) in greater proportion when compared, for example, to unilateral ZMO fractures (1 point) (Bagheri, Dierks et al. 2006). The FISS was used by You et al., who concluded that the severity of brain contusion and brain swelling was more frequently associated with a higher FISS (mild brain injuries with FISS ~ 3 points, and moderate to severe brain injuries with FISS ≥ 5 points) (You, Choi et al. 2018).

Indeed, the FISS system gives to isolated ZMO fractures a risk point-value of 1, indicating a low risk of brain injury, if compared to result of study previously mentioned. However, the results of present study revealed that geriatric patients diagnosed with unilateral ZMO fractures had a significantly higher risk for the presence of TBI when compared to younger controls (Study IV). This differs considerably from the results presented by You et al. (You, Choi et al. 2018). Based on the present results and previous publications (Hohlrieder, Hinterhoelzl et al. 2004, Patil, Patil et al. 2016, Ramneesh, Gulzar et al. 2014), the severity of isolated midfacial fractures should not be underestimated by using the existing scoring systems if they are not adjusted for facial trauma in the elderly.

6.5 Risk of under-triage and mortality in geriatric trauma

Despite awareness of the severity of geriatric trauma, elderly trauma patients are frequently under-diagnosed and under-triaged (Rogers, Rogers et al. 2012). The underestimation of geriatric trauma severity is an identified problem, the frequency of which varies from 15.0% to 69.1% in triage settings for elderly patients (Hung, Yeung et al. 2019, Garwe, Stewart et al. 2017, Harvey, Close 2012, Rogers, Rogers et al. 2012). The frequencies from the higher end of the range were presented by Hung et al., who observed that the frequency of under-triage increased as a function of age, being 59% between the ages of 55–70 years and as high as 69.1% in those over the age of 70 years (Hung, Yeung et al. 2019). Rogers et al. reported that the rate of mortality was nearly two times higher in under-triaged patients when compared to patients with the correct triage setting (Rogers, Rogers et al. 2012).

Geriatric patients are more often more severely injured and the elderly also die significantly more often due to their injuries in facial trauma, the frequency varying from 4.4% to 18.2% (Keller, Sciadini et al. 2012, Callaway, Wolfe 2007, Spaniolas, Cheng et al. 2010, Rau, Lin et al. 2014). The fall-related mortality in elderly trauma is notable (Spaniolas, Cheng et al. 2010), and has been associated with intracranial, spinal, and thoracic injuries, as well as with poor ISS, head AIs, age, and the need for ICU treatment (Spaniolas, Cheng et al. 2010, Ayoung-Chee, McIntyre et al. 2014). The mortality rate of 5.6% among the elderly diagnosed with all types of facial fractures (Study II) is clearly at a lower level when compared to the studies presented above. However, it is notable that mortality during hospitalization did not occur among the younger controls in present study. The underlying risk of death should not be underestimated, even in facial fractures of geriatric patients.

6.6 Future prospects

The development of three-dimensional computer assisted software systems has been rapid in the 21th century. In the future, the anatomical components, and the significance of intraorbital structures in orbital fractures, and the differences in younger patients and elderly might be investigated in more detail with increasingly common software.

The long-term clinical findings and symptoms in patients of different ages, particularly in orbital and ZMO fractures need to be examined prospectively in the future. The clinical long-term information is crucial to define our operative boundaries in facial fractures at different stages of life.

7. Key findings and conclusion

The results of the present study confirmed our hypotheses. There are significant differences in the causes and types of facial fractures between geriatric patients and younger adults. Moreover, associated injuries outside the facial region are significantly more frequent and severe in the elderly. The study revealed the following key findings and conclusions.

I. Female gender predominates among geriatric patients. A fall on the ground, especially during the cold and slippery period of the year, is by far the commonest cause of injury. In younger adults, on the other hand, male gender predominates, injuries are often sustained under the influence of alcohol, and assault is the commonest etiological factor. In the elderly, grip devices on shoes are recommended for the prevention of facial injuries.

II. In geriatric patients, the midface is by far the commonest fracture location. In particular, isolated ZMO and isolated orbital fractures should be suspected in the elderly, whereas mandibular injuries predominate in younger adults.

III. In geriatric patients, isolated unilateral orbital fractures are frequently extensive, involving the globe supporting the middle and posterior parts of the orbital wall more frequently than in younger adult patients. However, an altered ocular position is only present in one in five geriatric patients at the time of diagnosis, increasing the risk of missing relevant fractures that should be considered for reconstruction.

IV. Isolated ZMO fractures are frequently dislocated; however, clinical findings are minor in geriatric patients. Restriction of mandibular movement and asymmetry of the zygomatic prominence are absent significantly more often among the elderly than in younger adults, increasing the risk of ZMO fractures being undiagnosed in geriatric patients.

V. AIs are frequent and severe among geriatric patients diagnosed with facial fractures, and the elderly die more often due to their injuries when compared to younger controls. Elderly patients with isolated unilateral ZMO fractures are particularly prone to sustaining brain injuries, the risk being 5.3-fold higher than in younger adults. These findings emphasize the need for multi-professional collaboration in the diagnosis and primary sequencing of facial trauma treatment in the elderly.

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