PROSPECTIVE STUDY ON FUNCTIONAL OUTCOME OF DIAPHYSEAL FRACTURES OF SHAFT OF HUMERUS TREATED SURGICALLY WITH LOCKING COMPRESSION PLATES IN OSTEOPOROTIC BONES

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CERTIFICATE

This is to certify that **Dr. T.C. PREM KUMAR**, Postgraduate student (2006-2008) in the department of Orthopaedics, Government Kilpauk Medical College, Chennai has done this dissertation on "**PROSPECTIVE STUDY ON FUNCTIONAL OUTCOME OF DIAPHYSEAL FRACTURES OF SHAFT OF HUMERUS TREATED SURGICALLY WITH LOCKING COMPRESSION PLATES IN OSTEOPOROTIC BONES"** under my guidance and supervision in partial fulfillment of the regulation laid down by the Tamilnadu Dr. M.G.R Medical University, Chennai for MS (Orthopaedics) degree examination to be held on March 2008.

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CONTENTS

INTRODUCTION

Fractures of humeral diaphysis constitute 3% of all the bony injuries.[81] The uniqueness in anatomy, the fracture configuration and the significance of the region influences the treatment option.

The sleeve of muscles surrounding the bone and the rich vascularity provided by them helps in fracture healing. The mobility of the shoulder and the elbow joint accommodates for a minimal degree of angulation and shortening. Moreover the limb does not take part in weight bearing or ambulation; Hence some amount of shortening is functionally acceptable. But a rotational deformity is not acceptable.

Operative technique which have been devised for the treatment of humeral diaphyseal fractures include

- Open reduction and internal fixation with plate osteosynthesis
- Open or closed reduction and internal fixation with intramedullary fixation
- External fixation using ilizarov ring fixators or AO tubular fixators

Open reduction and internal fixation with plate osteosynthesis supplemented with bone grafting has been the gold standard for treatment of the humeral diaphysis when other methods are compared.[3,43,84,85]

It is associated with a high union rate, low complication rate and a rapid return to function. It can be used for fractures with both proximal and distal extension. It is safe and effective has essentially no elbow or shoulder morbidity and is stable enough to allow early upper extremity weight bearing in the multiply injured patient.[19,94]

Vander Griend et al reported union in 35 of 36 plated humeral fractures with no shoulder or elbow morbidity and one temporary radial nerve palsy.[95]

Bell et al had similar results ie., union in 37 of 39 fractures.[9,98]

Tingstad et al had union in 78 of 83 fractures.

The union rate following open reduction and internal fixation of humeral shaft fractures averages 96% in number of large series.[36,63,66,94,95]

Complications are infrequent and include *radial nerve palsy* (2-5%) usually *neuropraxic injuries* which usually recover, *Infection* (1-2%) for closed fractures, 2% to 5% for open fractures and *refracture* is 1%.

There are several practical advantages to the use of locking compression plates over standard compression plates.

Loss of screw purchase is an important factor related to the failure of fixation in *osteo porotic* bone. Fracture plating technology recently has evolved to include locked plating. ***The main goal is to obtain the most rigid fixation possible.***

Locking compression plates fixation is being evaluated for its effectiveness in the treatment of humeral diaphyseal fractures in osteoporotic bones.

AIM OF STUDY

Prospective study on functional outcome of diaphyseal fractures of shaft of humerus treated surgically with ***locking compression plate in mostly osteoporotic bones*** at Government Royapettah Hospital, Chennai between May 2006 and September 2007.

REVIEW OF LITERATURE

Diaphyseal fractures of the humerus account for 3% of all the fractures. The treatment concept for these fractures has been evolving over the time period. Historically closed methods of treatment for humeral diaphyseal fractures have centered around one of the two principles

1. Thoroco brachial immobilization and

2. Dependency traction

Thoroco brachial immobilization involved use of the body as a splint. This was achieved by using body strapping or by shoulder arm spica application. This method of treatment was not reliable for maintaining the alignment of the bone and promotion of bone healing.[49]

Caldwell promoted Hanging arm cast as a treatment option for management of humeral shaft fractures.[16,17] These are above elbow cast. They are stipulated to weight less than 2lbs., in order to avoid distraction. These casts are provided with series of loops, which are used to correct angulation deformities

U slabs or co-aptation splints were devised based on dependency traction. These are effective methods of treatment but functionally inferior to bracing.[16,49,50]

Treatment for humeral shaft fractures was revolutionized by the introduction of functional bracing by ***Sarmiento***. This is a fracture treatment orthosis made up of light weight plastic brace fitted with Velcro straps. This has provided excellent long term results with 100% union rate with minimal complications of malalignment infections and Iatrogenic nerve injury.[97]

Various studies have found bracing to be a much superior method of fracture treatment in otherwise normal individual.[58,90]

Operative intervention was found necessary in patients with malalignment. Klenerman et al and Balfour et al in different studies found that a valgus angulation of more than 15% unacceptable cosmetically though they found that this was not having any functional disability.

Bell, et al., proposed that humerus fractures must be fixed in cases of poly trauma.[9] Brumback suggested fixation for bilateral fractures of the humerus.

Broad dynamic compression plate was promoted by **AO/ASIF** for fracture stabilization. They noted complication rates of 7%hardware failures, 6%infection and 5% chances of iatrogenic nerve palsy. This is still considered the gold standard of treatment of fractures of the humeral diaphysis.[65,76,78]

Kunstcher first proposed intramedullary nailing for management of diaphyseal fractures of the femur, tibia and the humerus during the world war II. This was further promoted by Maatz.[14,18,43,52,62]

Flexible nails in multiple numbers can be inserted into the humerus from both the antegrade and the retro grade entry portal. The nails which have been in use are

- Enders nail
- Hackethal nail
- Rush nail

They were found to be having good prognostic outcome with 3% chances of *infection*, 9%chances of *nonunion* and *rarely migration* and *pseudarthrosis.*

Biological Internal fixation or bio buttress fixation is that one makes sense from biological point of view. Blind subcutaneous or submuscular insertion of an implant like a bone plate via a minimal surgical approach to preserve the vascularity and fixing it by the newer aiming and stabilizing technologies to achieve elastic flexible fixation.

The operative treatment of bone fractures using plates and screws is a standard successful technique. Internal fixation with plates and screws leads to additional trauma and disturbance of the bone blood supply, which increases the risk of delayed union and infection. However, problems also are encountered in the fixation of osteoporotic bone. The locked internal fixator technique is an approach to optimize internal fixation. It aims at flexible elastic fixation to imitate spontaneous healing, including induction of callus formation. The technology supports what is currently called "***minimally invasive plate osteosynthesis***" (MIPO), which provides priority to biology over mechanics. An implant system called "***Locking Compression Plate*** (LCP)" was developed,[7] based on many years of experience with compression plating and good clinical results obtained with internal fixators, such as the ***Less Invasive Stabilization Systems*** (LISS). It combines the two treatment methods (ie, the compression plating and locked internal fixation methods) into one system.

Locked internal fixator plate is designed to preserve biological integrity to enhance fracture healing, and to improve resistance to infection. In the setting of an *osteo porotic fractures* loss of purchase in the poor quality bone is high and it may be preferable to obtain an initial friction fit and protect this fixation with subsequent locking screws.[5,7] Additionally a compression screw may be used initially to appose the plate to the bone in order to optimize reduction.

OSTEOPOROSIS

Introduction

Osteoporosis is characterized by a reduction in bone mass and disruption of bone micro architecture resulting in increased bone fragility and increased fracture risk. The fragility fractures resulting from osteoporosis are a major cause of morbidity in the elderly population and impose a huge financial burden on health services. The sites most commonly affected by osteoporotic fractures are the *hip, spine, wrist, pelvis and humerus.* Although women are more commonly affected than men, osteoporosis is increasingly recognized as a major problem in the latter and it is estimated that, in Caucasian men and women aged 50 years, the lifetime risks of suffering an osteoporotic fracture are 20% and 15%, respectively. Due to impending demographic changes, the number and cost of fractures are predicted to increase at least twofold over the next 50 yrs.[72,88]

Osteoporosis is accelerated bone loss. Normally, there is loss of bone mass with aging, perhaps **0.7% per year** in adults. However, bone loss is greater in women past menopause than in men of the same age.[72]

A basic understanding of biomechanics of osteoporotic bone and its treatment is necessary for clinicians to establish appropriate treatment principles to minimize complications and enhance the patient's quality of life. We describe biomechanical considerations of osteoporosis and fracture treatment from various aspects.

Diaphyseal fractures can be reduced directly or indirectly independent of the technique any reduction maneuver should be as gentle as possible to the soft parts and periosteum surrounding the fracture. The aim being to preserve all existing blood supply.[40]

In treatment of diaphyseal fractures the fixation techniques used most commonly are intramedullary nailing plating and external fixation.

Bone quality influences the choice of fixation technique. Severe osteoporosis diminishes the holding power of screws or pins. So to increase the holding power of screws and to preserve the all existing blood supply and to reduce the chance of infection we have used locking compression plates in our series.

Diagnosis of osteoporosis is made by three methods:[68]

1. Radiographic measurement of bone density

2. Laboratory biochemical markers

3. Bone biopsy with pathologic assessment

Of these three the best is radiographic bone density measurement. A variety of techniques are available, including *single-photon absorptiometry, dual-photon absorptiometry, quantitative computed tomography, dual x-ray absorptiometry, and ultrasonography*

In our study we have used radiographic bone density measurement as to assess the quality of bone.

WHO criteria for Osteoporosis

T-Score:

CONDITIONS	BONE MINERAL DENSITY
Normal	> -1.0
Osteopenia	-1.0 to -2.5
Osteoporosis	< -2.5

ANATOMICAL CONSIDERATIONS

DEVELOPMENTAL ANATOMY[75]

The upper limb bud appears on the ventrolateral aspect of the body wall opposite the lower cervical segments at the end of the fourth week of embryonic life.

The humerus ossifies from one primary centres and seven secondary centres. The primary centre appears in the middle of diaphysis during the eighth week of development.

The upper end ossifies from three secondary centres, one for the head (first year) one for the greater tubercle (second year) and one for the lesser tubercle (fifth year). Three centres fused together during the sixth year to form one epiphysis which fuses with shaft during twentieth year.

The lower end ossifies from four centres which form two epiphysis. The centres include one for the capitulum and lateral flange of trochlea (first year), one for the medial flange of trochlea (ninth year) and one for the lateral epicondyle (twelfth year); all three fuse during the fourteenth year to form one epiphysis, which fuses with the shaft at about sixteen year. The centre for radial epicondyle appears during 4-6 years, forms a separate epiphysis, and fuses with shaft during the twentieth year.

Humerus is one of the four long bone complex of the appendicular skeleton. It forms the single bone scaffold of the arm segment. It is a long tubular bone with a diaphysis and globular proximal metaphysis. It is surrounded by a thick sleeve of muscle, which enhances the vascularity of the bone.

The shaft is rounded in the upper half and triangular in the lower half. The transition occurs at the mid diaphysis near the insertion of deltoid. It has three borders and three surfaces.

Borders:

1. The upper 1/3rd of the anterior border forms the lateral lip of the intertubercular sulcus. In its middle part, it forms the anterior margin of the deltoid tuberosity. The lower half of anterior border is smooth and rounded.

2. The lateral part is prominent only at the lower end where it forms the lateral supracondylar ridge. In the upper part it is barely traceable upto the posterior surface of the greater tubercle. In the middle part, it is interrupted by the radial or spiral groove.

3. The upper part of the medial border forms the medial lip of the intertuberculous sulcus. About its middle it represents a rough strip. It is continous below with the medial supracondylar ridge.

Surfaces:

1. The anterolateral surface lies between the anterior and lateral borders. The upper half the surface is covered by the deltoid. A little above the middle it is marked by V shaped deltoid tuberosity. Behind the deltoid tuberosity, the radial groove runs downwards and forwards across the surface.

2. The anteromedial surface lies between anterior and medial borders. Its upper 1/3rd is narrow and forms the floor of intertubercular sulcus. A nutrient foramen is seen on this surface near its middle, near the medial border.

3. The posterior surface lies between the medial and lateral borders. Its upper part is marked by a oblique ridge. The middle 1/3rd is crossed by radial groove.

DIAPHYSIS

Humeral diaphysis constitutes the middle three-fifths of the bone extending from the upper end of the pectoralis major to the supracondylar region. The proximal half of the diaphysis is broad and circular in cross section. It is grooved on its anterior aspect by the long head of biceps. In the distal half the bone flattens out into a triangular cross section. It has an anteromedial and an anterolateral surfaces flanked by medial and lateral supracondylar ridges. It also has a posterior surface. The lower end of the humerus in its juxta articular region is marked by the fossae to accommodate the olecranon posteriorly and the coronoid and the radial head anteriorly.

The medullary canal follows the contour of the humeral diaphysis. It is circular in its proximal half and is triangular in its distal half. It is broad proximally and tapers downs distally. The medullary canal is straight and is having an anterior offset towards the distal end.

PROXIMAL HUMERAL METAPHYSIS

Proximal humeral metaphysis is the broad globular end of the bone. It has an spheroidal head, which articulates with the glenoid. Apart from this the proximal end also has two bony prominences the greater and the lesser tuberosity. These landmarks are separated from each other by the presence of the bicepital groove. A shallow constriction separates the two tuberosities from the articulating surface. The constriction is the anatomical neck of the humerus. This is a significant landmark as the space between the articulating surface and the greater tuberosity forms the entry point for the interlocking nail in antegrade insertion technique.

DISTAL HUMERAL METAPHYSIS

Distal humeral metaphysis broadens mediolaterally and flattens anteroposteriorly. It is made up of the medial epicondyle, the trochlea, the capitelum and the lateral epicondyle mediolaterally. Between the distal articulating surface and the diaphysis are fossae for accommodating the olecranon posteriorly and the coronoid and radial head anteriorly.

The distal humeral articulating part is angulated anteriorly to the diaphysis by an angle of 40˚ to the diaphysial axis in the sagittal plane.

The diaphysis is supplied by a single nutrient vessel arising from the brachial artery in the mid shaft level.

SOFT TISSUE RELATIONS

The humerus is surrounded by the bulk sleeve of muscle, which provides for the better vascularity of the bone. There are three important neurovascular bundles, which weave around humerus, which becomes significant during the exposure of the bone.

MUSCULAR RELATIONS

Humerus is posteriorly related to the triceps, two of whose heads viz, lateral and medial originate from the posterior surface of the bone on either side of the radial groove. Anteriorly it is related to the biceps brachii, which does not have any attachment on to the humerus and the brachialis which originates from the anterior surface of the lower half of the bone. The deltoid covers the anterior, lateral and posterior aspect of the proximal half of the humerus.

MUSCULAR ATTACHMENTS

To the anatomical neck is attached the shoulder joint capsule and the capsular ligaments. The greater tuberosity gives insertion for the supraspinatus, the infraspinatus, and the teres minor from above downwards. Subscapularis gets inserted onto the lesser tuberosity.

Pectoralis major, the latissimus dorsi and the teres major gain insertion into the bicipital groove from before backwards. The deltoid is inserted onto the deltoid tuberosity on the lateral aspect of the middle of the shaft. Corresponding to the insertion of the deltoid, on the medial aspect is the insertion of the coracobrachialis.

The anteromedial and the anterolateral surfaces in the lower half of the humerus give origin to the brachialis. The posterior surface gives origin to the lateral and medial heads of the triceps above and below the bicepital groove. The medial and the lateral epicondyles are attached to the common flexor and the extensor origin. The lateral supracondylar ridge gives origin for the brachioradialis, extensor carpi radialis longus and brevis.

NEUROVASCULAR RELATIONS

Three important neurovascular bundles flank the humerus in its anatomical relations. The axillary nerve runs around the proximal metaphysis of the humerus supplying the deltoid. The radial nerve accompanied by the profunda brachial vessels runs around the posterior aspect of the humerus in the radial groove flanked by the medial and lateral head of the triceps. This structure is important in exposure of the humeral diaphysis by the posterior approach. Occasionally it may get entrapped in the fracture ending up with radial nerve palsy. The brachial vessels, the medial cutaneous nerves of the arm and forearm run in the space between the biceps and the brachialis.

CLASSIFICATION

There are no classifications for the humeral diaphyseal fractures good enough to prognosticate the outcome of the treatment. AOASIF has an elaborate system of classification of the fractures based on the fracture morphology, and the fracture site this comprehensive system is of prognostic value, in that the greater the grade of fractures the higher the energy of injury, implying greater the chances of occurrence of complications during treatment.

AO ASIF CLASSIFICATION OF HUMERAL DIAPHYSEAL FRACTURES[81]

TYPE-A simple fractures

Circumferential break in the bone

A1- spiral fractures

1. in the proximal zone
2. in the middle zone
3. in the distal zone

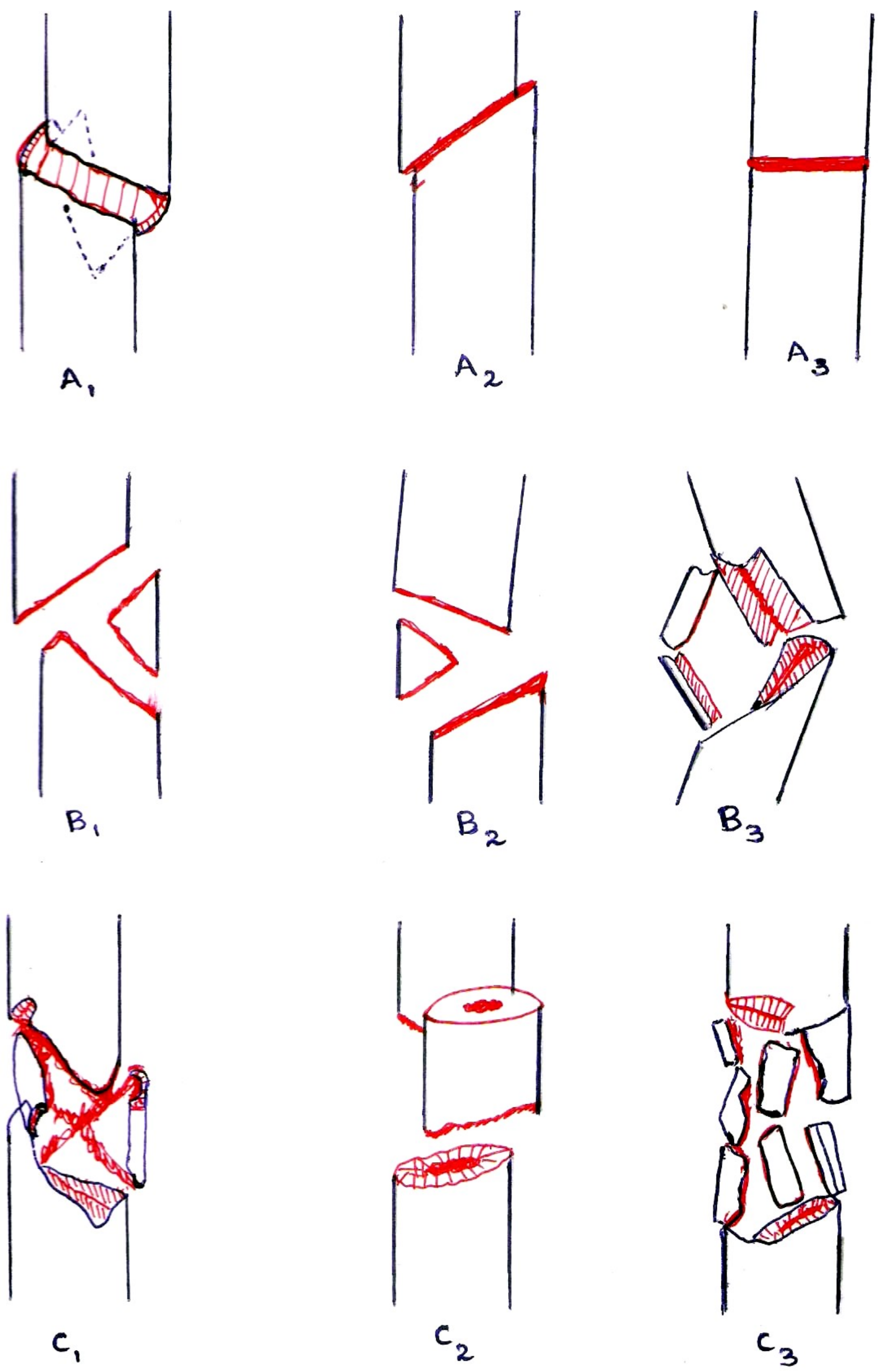
A2-oblique fractures i.e fracture lies at 30° or more to the diaphysis.

1. in the proximal zone
2. in the middle zone
3. in the distal zone

A3-transverse fractures .i.e fracture lies <30° to the diaphysis.

1. in the proximal zone
2. in the middle zone
3. in the distal zone

AO CLASSIFICATION OF HUMERAL SHAFT FRACTURES



TYPE-B wedge fractures.

Separate butterfly fragment, but the fracture reduces with contact between the main fracture fragments.

B1-spiral wedge as a result of torsional forces.

1. in the proximal zone

2. in the middle zone

3. in the distal zone

B2-bending wedge as a result of bending stresses.

1. in the proximal zone

2. in the middle zone

3. in the distal zone

B3-bending wedge where the wedge is communited.

1. in the proximal zone

2. in the middle zone

3. in the distal zone

TYPE-C: complex fractures.

There are more than two fragments and even after reduction the main fragments do not come in contact.

C1-spiral

1. with two intermediate fragments
2. with three intermediate fragments
3. with more than three intermediate fragments

C2-segmental

1. with one intermediate segment
2. with one intermediate segment and a butterfly fragment
3. with two intermediate segments

C3-irregular fractures

1. with two or three intermediate fragments
2. with shattering of the bone for a length of <4cms
3. with shattering of the bone for a length of >4cms

MECHANISM OF INJURY

The predominant causes of humeral shaft fractures include ***simple falls or rotational injuries in the older population*** and ***higher-energy mechanisms in the younger patients including motor vehicle accidents, assaults, falls from a height and throwing injuries.***[64,81]

A history of minimal trauma causing fracture in older patient may be the first point to alert the surgeon that the fracture may involve pathologic bone (be it from metastatic disease or severe osteoporosis) and prompt a thorough history (eg., for prior cancer) and possibly a systemic work-up. In this situation the treating surgeon has the potential to help the patient both in terms of presenting fracture and the prevention of further fractures.

The described mechanism of injury should match the fracture type: while exceptions do occur. The presence of a spiral fracture indicates a rotational force (such as that which occurs when the arm is forcefully wrenched behind the back) that is not consistent with, for example, striking the arm against the door.

Discordance between history and fracture type is a hallmark of domestic abuse, and again this may represent an opportunity to intervene in a potentially lethal situation. Alcohol abuse, smoking, and / or illicit drug use are all potential risk factors for negative fracture outcome through repeat injury, non- compliance, or poor biology at the fracture site, and represent an opportunity to improve outcome.

TREATMENT PROTOCOL

Fractures of the humeral diaphysis are commonly associated with other systemic injuries viz, thoracic injuries, facio maxillary and injury to the brachial plexus. These more life threatening injuries must be looked for and treated immediately. Any neurovascular involvement especially that of radial nerve and the brachial vessels must be checked for.[15]

The humeral diaphyseal fractures are treated with closed reduction and co aptation splinting. This can be the definitive treatment if the reduction is satisfactory and there are no neurovascular complications.[47]

Indications for primary operative treatment of humeral shaft fractures

I. *Fracture indications*:

- Failure to obtain and maintain adequate closed reduction; Shortening >3cm,

  Rotation >30˚

  Angulation > 20˚

- Segmental fractures.
- Pathological fractures
- Intra articular extension.

  1. Shoulder joint

  2. Elbow joint

II. *Associated injuries*[12,56]

- Open wound
- Vascular injury
- Brachial plexus injury
- Ipsilateral forearm fractures
- Ipsilateral shoulder or elbow fractures
- Bilateral humeral fractures
- Lower extremity fractures requiring upper extremity weight bearing.
- Burns
- High velocity gun shot injury
- Chronic associated joint stiffness shoulder & elbow.

III. *Patient indications*

- Polytruama[9]
- Head injury (GCS $\leq$ 8)
- Chest trauma
- Poor patient compliance
- Unfavorable body habitus:
    - morbid obesity,
    - large breast

Surgery is contemplated in following situations[55,57,58]

- Inability to maintain fracture alignment in normal bracing ie., more than 15˚of angulation or rotational deformity.
- Non compliance
- Poly trauma
- Spinal injury
- Lower extremity injury
- Long bone fractures involving the same limb
- Pathological fractures
- Brachial plexus injury
- Brachial artery injury
- Bilateral humeral fractures
- Segmental fractures

GENERAL PRINCIPLES OF MANAGEMENT

Sixty percent humeral diaphyseal fractures are associated with poly trauma. Hence these systemic problems must be sought after and treated before the definitive management of humeral fractures.[67]

AVAILABLE TREATMENT OPTIONS

1. Thoraco brachial immobilization
2. Closed reduction and hanging arm cast co-aptation splinting
3. Closed reduction and co-aptation splinting
4. Closed reduction and internal fixation with

a. Plate osteosynthesis

   i. Dynamic compression plates
   ii. LC-DCP Plate
   iii. Locking Compression Plates

b. Intramedullary nailing

   i. Multiple nails
   ii. Flexible nails
   iii. Solid nails

5. Closed reduction and internal fixation with a intramedullary interlocking nailing
6. External fixators application with
   a. AO external fixators
   b. Ilizarov ring fixator

Locked internal fixator plate

The locking compression plate[2,4] was designed using the concept of "***internal fixator***," which provides a new solution for the fixation of osteoporotic fractures. The fixed angle between the screw and the plate increases the pull-out strength of the system, so the stability of the fixation no longer depends totally on the quality of the bone. The other benefits of this system include the fact that no accurate contouring is required, it protects the local blood supply, and it supports minimally invasive plate osteosynthesis.

At the beginning modern era of plate fixation in early sixties, rigid internal fixation to achieve direct bone healing was a laudable goal. Bone fragments were extensively handled to accomplish perfect anatomical reduction and were fixed with heavy implants to regain mobility in immediate postoperative period.

Wide exposure of the bone was necessary to gain access and to provide good visibility of the fracture zone to permit reduction and plate fixation. The screws had to be tightened to compress and fix the plate onto the bone. The stability resulted from friction between the plate undersurface and the bone.[130,32]

Tightly fixed implants as well as extensive bone and soft tissue handling lead to *bone avascularity* and *necrosis,* which was noted as *porosis* beneath the plate on early postoperative x-rays. This bone loss in the vicinity of a plate was explained on the basis of Wolf's law as a reaction of living bone to mechanical unloading of the plated bone segment (stress protection). During the lengthy fracture healing process, the plate had to be left in place and return to full level of activity had to be delayed. Direct healing is still important mechanism when necrotic bone must heal and therefore compression technique are an important tool when dealing with damaged bone.

Once the true nature of these events were uncovered, the priorities changed from *mechanical stability to biology*.[8] The ***biological internal fixation*** of bio-buttress fixation is one that makes sense from biological point of view. Blind, subcutaneous or submuscular insertion of an implant like a bone plate via a minimal surgical approach to preserve vascularity and fixing it by the newer aiming and stabilizing technologies to achieve elastic flexible fixation is part of this protocol.

The locked internal fixator plate represents a novel, bio-friendly approach to internal fixation. It resembles a plate but its biological and mechanical characteristics are different and it functions rather like fully implanted external fixator, even in its healing pattern. A locking plate construct might be considered the ultimate external fixator with minimal soft tissue dissection, wide screw spacing, locked screws and the plate functioning as the connecting bar, placed extremely close to the mechanical axis of the bone.[38]

LIFP is designed to preserve biological integrity to enhance fracture healing and to improve resistance to infection. It is a construct where a screw with threaded head (akin to a pin of an external fixator) is locked in the threaded hole in bone plate (replacing the frame of an external fixator) and the forces transferred from the bone to the fixator across the threaded screw-fixator connection. Instead of pressing the splint, the screw with threaded head acts as a peg connecting the splint to the bone. The screw of the internal fixator is actually more like a threaded bolt. The bolt transfers more bending load than conventional screw and its core is therefore thicker than that of the conventional screw. Locking the screw in the fixator abolishes force transmitted by friction, minimizes bone contact, increases stability and eliminates the risk of loss of reduction due to toggling of the screw in the bone.[24,25]

The mechanical performance of LIFP is comparable to that of conventional plates for subyield loads typical of post- treatment restricted weight bearing. In large bones LIFP offers higher weight bearing capacity than conventional plates. LIFP offers a new load transfer concept.[32,44] Locking of the screws in LIFP and the very close proximity of the LIFP to the bone allows for the use of monocortical screws without a compromise in the strength of the construct or the stability of the fixation. The holding power along the long axis a monocortical screw is less than half of a bicortical screw. The number of monocortical screws required depend on their spacing, their loading, and on the quality of bone. Current recommendation is to use three well-spaced monocortical screws where one would conventionally engage five cortices. In poor quality bone, bocortical engagement is recommended.[44]

From the days of ***Hansman-1886, Lambotte, Danisto AO group***, osteosynthesis by plate fixation has evolved to betterment bringing about solace to patient. But the evolution has seen its fair share of obstacles and over time Greatmen have overcome them by designing better fixation devices.

Primary bone healing became a reality in 1960’s and early 1970’s with the advent of new philosophies in fracture treatment and the advent of semitubular and compression devices. In the late 1970’sthe *dynamic compression plate* was introduced which dawned the era of compression at the fracture site with a single implant. It also minimized the use of external compression devices. This invention was then followed by the limited contact DCP (LC-DCP) which was designed with trapezoid cross section, to decrease the damaging footprint of the plate on the periosteum.[66] Surgeons soon came to realize the importance of preserving the bone micro anatomy for achieving better results. The damage caused by violating the periosteum by DCP and to some extent LC-DCP has been shown with many biochemical markers and stains. After 20 yrs of advocating absolute stability, the masters of plate osteosynthesis now are suggesting the concept of biological fixation.

The new mantra; “BONE IS LIVING TISSUE” prompted surgeons to device new techniques. MIPPO - *minimally invasive percutaneous plate osteosynthesis*[99,100] came into vogue in late 1980”s. indirect fracture reduction was used. It can tolerate imperfect reduction because fracture was not disturbed. But the screw pullout which was a major problem was to be answered. Researchers designers and surgeons all started experimenting with plate design and how the screw could be fixed rigidly to the plate. Initially this was limited to plates used by MIPPO technique, also known as LISS- less invasive stabilization system used for distal metaphyseal fractures of femur.[53]

Richard Wagnoer, combined the principles of compression with that of locking plates used in the LISS system[42,48] to come out with the present day LOCKING COMPRESSION PLATE. It is ideal combination of two well known anchorage concepts;[44,85,96]

- ***Compression plate***
- ***Internal fixator.***

Poor bone quality increases the technical difficulty and complications of operative treatment of non unions and delayed unions of the diaphyseal humerus in older patients. Plates with screws that lock to the plate (transforming each screw into a fixed blade) are intended to improve the fixation of poor quality bone.[29,69,79]

The literature demonstrates low rates of nonunion and overall complication rates with locking plates in difficult metaphyseal and diaphyseal fractures.

Use of plating with bicortical locked screws as an alternative to conventional plating for comminuted diaphyseal fractures in osteoporotic bone. Bicortical locked screws with minimal displacement from the bone surface provide the most stable construct in the tested synthetic comminuted diaphyseal fracture model.[28,60]

Features;

- LCP's are single beam construct by design, no motion occurs between the components of beam, i.e., plate, screw & bone.
- They are four times stronger than load sharing constructs where motion occurs between individual components of the beam constructs.
- Stable bridging & excellent securing of the fracture with angularly stable locking.
- No primary & secondary loss of correction due to stable plate screw constructs.
- Reduced vascular & periosteal damage beneath the plate.
- Reduced screw loosening thanks to the locking screws.
- No thread stripping in cortical bone.
- Availability of preshaped plates.
- Excellent distribution of forces around screws.
- Locking screws or standard screws can be inserted through combination hole or integrated hole.

- Easy insertion due to tapered plate tip &suited for MIPPO technique-with less damage to tissues and periosteum.[100]

LCP is choice in;

- Osteoporotic bones
- Juxtra-articular fractures
- MIPPO technique-reduction is made easy
- Badly shattered communited fracture of long bones
- Periprosthetic fractures

Some tips and pearls of LCP fixation are;

- Atleast 3 screws on either side of the fracture
- Screw holes nearest to fracture have to be used without fail
- All the holes need not to be fixed
- Compression screw should be farther away from the fracture and on one side only
- Plate should be in compression mode in transverse or minimally communited fractures
- Use of a longer plate provides better axial stiffness the as the working arm is more.

BIOMECHANICS OF LIFP

LIFP and compression plates rely on completely different mechanical principles to provide fracture fixation and in doing so make available for different biologic environments conducive to bone healing.[30] A fracture heals if it is stable. The level of stability decides the extent of movements occurring at the fracture site. More the stability, lesser the movement.

Primary bone healing occurs only if the movement at the fracture site is bare minimum, i.e. the strain level is less than 2 percent.

Secondary bone healing occurs when the tissue elongation is 2-10%. In contrast, granulation tissue tolerates greater level of elongation and grows in the face of 100% strain levels.

Locked compression plate is ***single beam construct*** by design acts as a ***fixed angle device***. Functioning as a fixed angle device the plate enhances fracture fixation in circumstances where fracture configuration or bone quality does not provide sufficient screw purchase to achieve plate bone compression necessary to minimize gap strain with conventional plate screw construct.

It controls the axial orientation of the screw to the plate, thereby enhancing screw plate bone construct stability.[1,30,32,51,92] In a single beam construct, there is no motion between the components of the beam ie., the plate screw and bone. It is four time stronger than the load sharing beam construct where motion occurs between the individual components of the beam construct.

Locking compression plate converts shear stress to compressive stress at screw bone interface; fixation is improved because bone has much higher resistance to compressive stress than shear stress.

The key to this new generation of plates is the locking mechanism of the screw to the plate, which provides angular stability and avoids compression of the plate to the periosteum. In locked plates, strength of fixation equals the sum of all screw bone interfaces rather than that of single screw's axial stiffness or pull out resistance as seen in conventional plates. The inherent angular and axial stability further improve fixation.

Locked plates act as ***'internal-external fixator'*** and are extremely rigid close proximity of the bone and fracture site. Short screw length of the locked plate increases its stability substantially. Strain at the fracture site is optimized, so that secondary bone healing with callous formation is favored over fibrous non union or primary bone healing. Stability across the fracture becomes the function of the mechanical properties of the plate.[33,38]

As an internal fixator locked plate no longer relies on frictional force between the plate and the bone to achieve compression and absolute stability. The blood supply to the periosteum is preserved that allows rapid bone healing. Maintained bone perfusion decreases infection rate, bone resorption, delayed and non union, and secondary loss of reduction.

A further increase in utility of LIFP is achieved by combining the self compressing unit hole and locked internal fixator threaded hole. This integrated hole makes it possible to exploit and combine the advantages of conventional plates and screws as well as LIFP. The traditional self compressing unit permits dynamic compression by eccentric placement of standard screws as well as by lag screw technique to obtain maximal interface compression. The threaded screw head and appropriately threaded plate hole offer angular stability, provide better anchorage, eliminate toggling and reduce the risk of reduction loss.

A plate with ***integrated hole*** offers three alternatives

1. fixation with conventional screws
2. fixation with locking head screws
3. fixation with combination of conventional and threaded head screws

Precise anatomical contouring of the plate is no longer necessary because LIFP does not need to be pressed onto the bone to achieve the stability. When locked screws are applied in divergent or convergent inclination in relation to each other they provide better resistance to pull out than parallel screws. When loaded perpendicular to its long axis, the shallow threaded screw cuts less into soft bone than a traditional screw with its sharp edges. The threaded head screw is especially suitable in osteoporotic bone.

Two screws per main fragment with purchase of at least three cortices for simple fracture and at least two screws per main fragment with purchase of at least four cortices for comminuted fractures is sound practice to follow. ***Monocortical*** screws require secure purchase in near cortex and will have insufficient purchase to provide stable fixation in metaphyseal bone with a minimal cortex. When in doubt ***bicortical*** purchase should be obtained.[28,60]

Biomechanical study of Davenport showed no difference in stress between unicortical and bicortical screws in the end of plate and this technique is no longer recommended.[61]

A locking head screw exhibits high stability with a moderate axis deviation in the angle of insertion of up to 5 degrees. However, there is a significant decrease in stability with increasing axis deviation (>5 degrees). At a distance 5 mm we observe an inferior performance in the mechanical properties of the LCP construct with decrease in axial stiffness and torsional rigidity. If it is desirable for an LCP to be used the distance between plate and bone should be <or=2 mm. An aiming device is recommended to provide optimal fixation with angular stability.

The locking internal fixator is a symbiosis of various techniques of plate osteosynthesis. LIFP offers a versatile easy to use and purposeful design to improve the surgical approach to fracture treatment.

Advantages:

Reduction of vascular damage

Resistance to infections[31]

Disadvantages:[45a]

The surgeon has no tactile feed back as to quality of screw purchase in to the bone as he tighten the screw because the screw locked into the plate, all screws abruptly stop advancing when the threads are completely seated into the plate.

Current locked plate designs can be used to maintain fracture reduction, but not to obtain it.

No further reduction adjustment are possible unless the screws are completely removed.

Inability of the surgeon to alter the angle of the screw within the hole and still achieve a locked screw.

Any attempt to contour locked plate would potentially distort the screw holes and adversely affect the screw purchase.

Hardware removal may be more difficult, torque limiting screw drivers may be necessary.[93a]

Angle stable plate may be unidirectional or multidirectional.

Unidirectional angular stability plate was first reported by Reinhold (1931). It is thread in thread principle that is familiar from screws and nuts.

Multidirectional angular stability allows screws to be locked in the plate holes in any position. An expanding washer allows a screw put in desired direction.[92a]

In the setting of an osteo porotic factures loss of purchase in the poor quality bone is high and it may be preferable to obtain an initial friction fit and protect this fixation with subsequent locking screws.[5,7] Additionally a compression screw may be used initially to appose the plate to the bone in order to optimize reduction.

Osteoporosis is no longer considered a contraindication to operative fixation of an ununited fracture of the humeral diaphysis.

SURGICAL APPROACHES AND APPLIED SURGICAL ANATOMY

Although number of surgical approaches to the humeral shaft have been described there are two standard techniques dominate most articles and reviews and are most commonly used clinically.[13,90,91]

- **The posterior approach**
- **The anterolateral approach**

Other described approaches that are useful in special situations are

- The direct lateral approach
- The direct medial approach

Only the approaches that we have used in our study has been dealt below.

Anterolateral approach to the humerus:

This approach is preferred option for majority of proximal and middle third humeral shaft fractures that require plate fixation.

Position of the patient

Place the patient supine on the operating table, with the arm lying on an arm board and abducted about 60° exsanguinate the limb either by elevating it for 3 minutes or by applying a soft rubber bandage; then apply a tourniquet in as high a position as possible in distal humeral fractures.

Skin incision is centered over the fracture site and performed longitudinally along the palpable lateral border of biceps brachii.

Landmark: Proximally corocoid process

Distally anterior to lateral supracondylar ridge

Proximal Dissection: between pectoralis major medially and deltoid laterally.

Take care to identify and protect the cephalic vein.

If required, broad deltoid insertion can be reflected posteriorly to gain access to anterolateral shaft.

Mid shaft region: dissection plane between the biceps and triceps exposing the brachialis underneath which is split longitudinally along with lateral portion.

Split is roughly in internervous plane.

Distally: dissection along the anterior aspect of the lateral supracondylar ridge between the brachialis medially and brachioradialis laterally. At this point radial nerve is closest to dissection, so it should be identified and protected.

Advantages:

- Favorable position of the patient – for poly trauma cases
- Incision can be extended proximally to deal with associated shoulder pathology or proximal extension of a fracture.
- Identification of radial nerve distally.

Disadvantages:

- Technically difficult to apply a plate distally along the (thin) lateral supracondylar ridge.
- Lack of access to any medial column pathology.
- Noticeable scar results.

Posterior approach:

Posterior approach is ideal for fracture that involves distal third of fractures especially that have intraarticular extension or that require exploration and repair of associated radial nerve injury.

Posterior approach:

Position of the patient

Two positions of the patient are possible during surgery; a lateral position on the operating table with the affected side uppermost or a prone position on the operating table with the arm abducted 90˚. A sand bag should be placed under the shoulder of the side to be operated on, and the elbow should be allowed to bend and the forearm to hang over the side of the table. A tourniquet should not be used because it will get in the way.

Skin incision is centered over the fracture site.

Landmark: proximally posterolateral corner of the acromion

Distally tip of acromion

Triceps sharply divided distally taking care to identify and protect the radial nerve (and profunda brachii artery that runs with it) proximally

The radial nerve crosses the posterior aspect of the humerus in the spiral groove roughly equidistant between the tip of olecranon and the edge of acromion, and can be identified at the lateral edge of attachment of medial haed of triceps.

Proximally it is possible to identify the interval between the long and lateral heads os triceps.

Distally if fixation is anticipated on the medial column of humerus, the ulnar nerve has to be identified and protected.

Advantages:

- Ability to access both lateral and medial column distally.
- Easy to fix a shaft fracture with distal extension.
- Flat posterior surface distally is ideal for plate fixation.

Disadvantage:

- Injury to radial nerve
- Prone or lateral position of the patient is not favorable in multiply injured patients.
- Humeral head and neck cannot be accessed safely through this approach

AO PRINCIPLES OF FIXATION

AO/ASIF formulated the following treatment guidelines based on **Lambotte's principles** of surgical treatment of fractures.[76]

In **1958** the **AO ASIF** (association for the study of internal fixation) formulated four basic principles which have later become the basic principles of internal fixation. Those principles as applied to the LCP are

1. Anatomical reduction

Exact screw placement utilizing wire sleeves facilitates restoration of articular surface.

2. Stable fixation

Locking screws provide a fixed angle construct providing angular stability.

3. Preservation of blood supply

Tapered end for sub muscular plate insertion improving tissue viability limited contact plate design reduces plate to bone contact minimizing vascular trauma.

4. Early mobilization

Plate features combined with AO technique create an environment for bone healing expediting a return to optimal function.

MATERIALS AND METHODS

This prospective study is an analysis of functional outcome of 20 cases of surgically managed diaphyseal fractures of shaft of humerus in mostly osteoporotic bones and in fracture non-unions undertaken at ***Department of orthopedics and traumatology, Government Royapettah hospital, Chennai. From May 2006 to September 2007.***

TABLE - 1

SEX DISTRIBUTION

S. No	Sex	No. of patients	Percentage
1	Females	12	60
2	Male	8	40

Among the 20 patients 12 were females and 8 patients were males. The age of the patients ranged from 53 years to 83 years. The mean age of the patients was 67.15 years.

TABLE - II

AGE DISTRIBUTION

S.NO	AGE GROUP	NO. OF PATIENTS	PERCENTAGE	MALES	FEMALES
1	51-60	3	15	1	2
2	60-70	10	50	4	6
3	>70	7	35	3	4

The mode of injury was fall at ground level in 12 (60%) of patients, road traffic accidents in 6 (30%) patients, fall from height in2 (10%) patients.

TABLE - III

MODE OF INJURY

S.NO	MODE OF INJURY	NO. OF PATIENTS	PERCENTAGE
1	Fall at ground level	12	60
2	RTA	6	30
3	Fall from height	2	10

TABLE - IV

OCCUPATION

S.NO	OCCUPATION	NO.OF PATIENTS
1	Laborer	3
2	House wife	8
3	Skilled worker	6
4	Professional	1
5	Business	1

TABLE – V

S.NO	SIDE	NO.OF PATIENTS
1	Unilateral	20
2	Bilateral	0

TABLE – VI

SIDE

S.NO	SIDE INVOLVED	NO.OF PATIENTS
1	Dominant(right)	16
2	Non-dominant(left)	4

Sixteen patients presented to us within a week after injury and 8 patients had previous treatment either in the form of native splinting, massage or POP cast. (TABLE-VII).

TABLE - VII

DURATION

S.NO	NO.OF DAYS SINCE INJURY	NO.OF PATIENTS
1	0-7 DAYS	15
2	8-14 DAYS	3
3	15-21 DAYS	2

TABLE -VIII

PREVIOUS TREATMENT

S.NO	PREVIOUS TREATMENT	NO.OF PATIENTS	PERCENTAGE
1	Massage	2	10
2	Massage and splinting	1	5
3	Splinting	2	10
4	Attempted reduction with splinting	1	5
5	POP Immobilization	2	10
6	No native treatment	12	60

A meticulous clinical examination was made in all patients with care to look for any associated injuries. 8 patients had associated injuries ipsilateral skeletal injuries which were concomitantly treated. (TABLE-X)

TABLE - IX

S.NO	FRACTURE	NO.OF.PATIENTS
1	Closed fracture	20
2	Open fracture	0

TABLE - X

S.NO	ASSOCIATED INJURIES	NO.OF.PATIENTS
1	Fracture forearm bones	2
2	Fracture distal radius	1
3	Fracture metacarpal	2
4	Fracture neck of femur	1
5	Shoulder dislocations	0
6	Elbow dislocations	0
7	Others	0

Standard anteroposterior and lateral radiographs of the affected humerus were taken in all patients that include the shoulder and elbow joints in each view. Further views ordered depending on the clinical examination and any abnormalities noticed on initial films. Angiogram and computed tomograms should be taken when there is associated vascular injury and to assess the rotational abnormality. Ultrasound is an effective alternative to rule out fracture in doubtful cases

TABLE - XI

IMAGING

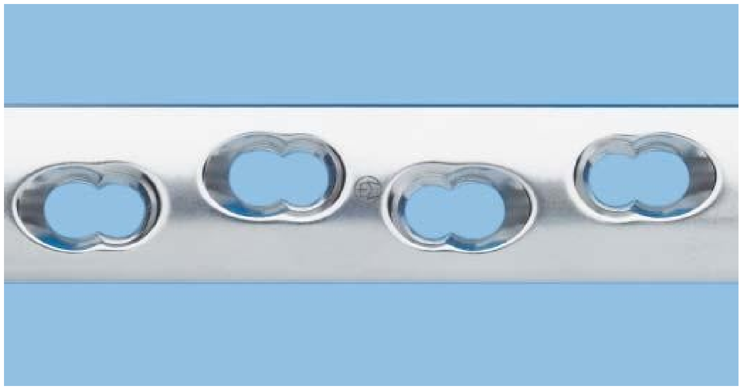
S.NO	IMAGING	NO.OF PATIENTS
1	X-rays	20
2	Bone densitometry	20
3	CT scan	0
4	Ultrasound	0
5	Angiography	0

TABLE - XII

TYPE OF FRACTURE

S.NO	AO-TYPE	NO.OF PATIENTS	PERCENTAGE
1	A1.2	7	35
2	A2.2	2	10
3	A3.2	3	15
4	B1.2	4	20
5	B2.2	2	10
6	B3.2	1	5
7	C1.2	1	5
8	C2.2	0	0
9	C3.2	0	0

INSTRUMENTATION



The following points distinguish treatment using Locking Compression Plate technology:

- Allows fracture treatment using conventional plating with conventional cortex or cancellous bone screws.
- Allows fracture treatment using locked plating with bicortical or unicortical locking screws.
- Permits the combination of conventional and locking screw techniques.

The Locking Compression Plates (LCP) have these LC-DCP features:

- 50° of longitudinal screw angulation
- 14° of transverse screw angulation
- Uniform hole spacing
- Load (compression) and neutral screw positions screws

Combination Locking and Compression (Combi Hole):[11]

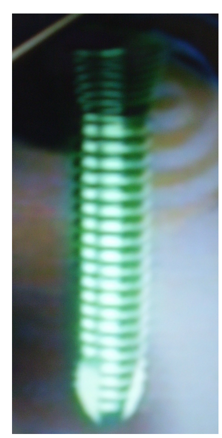
The Combi holes allow placement of conventional cortex and cancellous bone on one side or threaded conical locking screws on the opposite side of each hole.

a. Threaded hole section for locking screws
b. DCU hole section for conventional screws
c. Locking screw in threaded side of Combi
d. Cortex screw in compression side of Combi hole

Note: Combi holes in straight plates are oriented with the conventional portion of each hole further from the middle of the plate. This facilitates utilization of LCP plates for dynamic compression using traditional AO techniques.

Locking threads mate with the plates
Self-tapping flutes Cortical thread profile
Locking Screws
Locking Screw Design

The screw design has been modified, from standard 4.5 mm cortex screw design, to enhance fixation and facilitate the surgical procedure.



New Features Include:

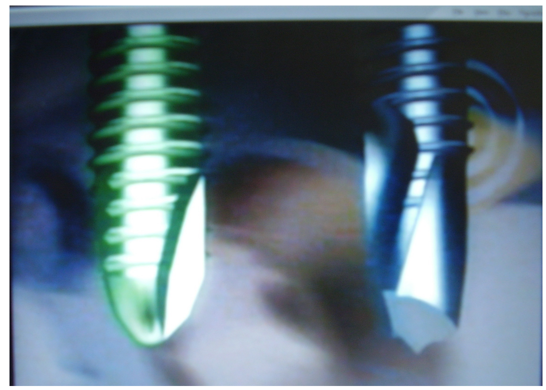
Conical Screw Head

The conical head facilitates alignment of the locking screw in the threaded plate hole to provide a fixed angle connection between the screw and the plate.

Large Core Diameter

The large core diameter improves bending and shear strength of the screw, and distributes the load over a larger area in the bone.

Thread Profile



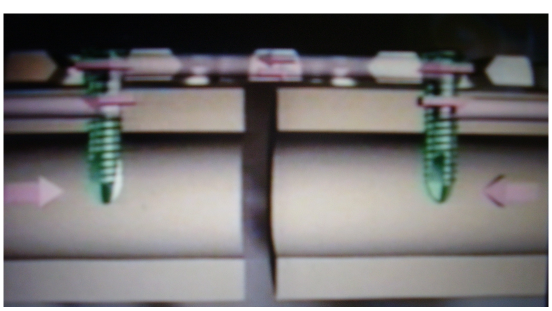
The shallow thread profile of the locking screws results from the larger core diameter and is acceptable because locking screws do not rely solely on screw purchase in the bone to maintain stability.

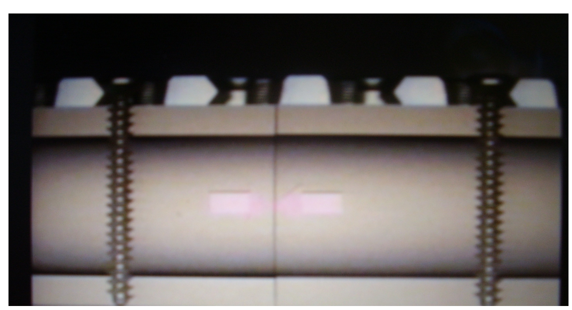
Drive Mechanism

The StarDrive recess provides improved torque transmission to the screw, while retaining the screw without the use of a holding sleeve.

Unicortical Screw Fixation

Bicortical screw fixation has long been the traditional method of compressing a plate to the bone where friction between the plate and the bone maintains stability. Screw stability and load transfer are accomplished at two points along the screw: the near and far cortices.





Unicortical locking screws provide stability and load transfer only at the near cortex due to the threaded connection between the plate and the screw. Screw stability and load transfer are accomplished at two points along the screw: the screw head and near cortex. Because the screw is locked to the plate, fixation does not rely solely on the pullout strength of the screw or on maintaining friction between the plate and the bone.

In osteoporosis or poor quality bone bicortical engagement is recommended.

Post op rehabilitation[10,37,41,94]

In all patients the arm was placed in an arm sling and POP applied if fixation was not stable. Prophylactic antibiotics which were started before surgery were continued for 48 and 72 hours postoperatively. Sutures were removed by 10th post operative day.

Phase I exercises consisting of active finger movements, and pendulum exercises of shoulder joint were encouraged from the first week.

Phase II exercises consisting of active range of motion exercises of shoulder and elbow were started by 3 to 6 weeks.

Phase III exercises consisting of advanced stretching and strengthening exercises were started by 3 months.

Gradual weight lifting started after 3 months.

TABLE - XIII

POST OP IMMOBILISATION

S.NO.	IMMOBILISATION	NO. OF PATIENTS
1	Post op POP	2
2	Arm sling	12
3	Shoulder immobilizer	4
4	Cuff and collar	2

All the patients were followed up monthly for the first three months and later, every 3 months .During follow-up patients were clinically evaluated for pain, function and rotation. Radiological evaluation of fracture union was observed by serial x-rays.

OBSERVATIONS

Majority of injured patients were females (60%)

Highest number of patients were in the 6th decade.

Free fall at ground level was the most common mode of injury.

There was no case with bilateral fractures.

All were right handed persons and the dominant arm was involved in 16 (80%) patients.

Post menopausal osteoporotic females accounted for 60% of patients.

10 patients reported to hospital on the day of injury.

30% of patients had undergone previous native treatment either in form of massage or splinting.

4patients had associated fractures.

All the patients had closed injuries.

AO Type A is the most common type in 60 % patients.

Type B is the next common type in 35%patients.

Type C accounted for only 5% of patients.

Post operative immobilization with POP was used in 4 patients.

Patients were taken up for surgery on an average of 8 days after injury.

All the patients were treated with Locking compression plate.

Bone grafting was done for all communited fractures.

Average follow up period was 10.5 months.

50% patients do not have any pain during follow-up.

Patients with Type A fracture had a better functional outcome than Type B or Type C fractures.

19 of 20 fractures united within a period of 16 months.

The average time of union was 14.5 weeks.

One patient had delayed union for whom secondary bone grafting was done and united after 24 weeks.

95% of fractures united within 16 weeks.

The functional outcome was more that 90%.

COMPLICATIONS

Early complications:

Early complications were encountered in 4 (20%) patients.

- Two patients with diabetes mellitus had wound gaping requiring secondary suturing after glycemic control.
- One patient with comminuted humeral shaft fracture developed skin necrosis which resolved after serial wound dressing.
- One patient had Transient Radial nerve palsy after surgery which improved with cock up splint and electrical stimulation of wrist extensors.[6,27,89]

EARLY COMPLICATIONS

SL NO	COMPLICATIONS	NO. OF PATIENTS
1	Skin necrosis	1
2	Wound gaping	2
3	Radial nerve palsy	1
4	Infection	0

Late complications

Late complications were encountered in 3 patients.

- Two patients had shoulder joint stiffness probably because the patient had undergone native treatment with massage and attempted reductions and surgery was performed one month after injury both of them recovered after physiotherapy.

- One patient had delayed union probably because the bone was osteoporotic and associated co-morbid conditions.

TABLE- XV

LATE COMPLICATIONS

SL NO	COMPLICATIONS	NO. OF PATIENTS
1	Shoulder stiffness	2
2	Elbow stiffness	0
3	Delayed union	1
4	Non union	0
5	Implant failure	0
6	Pseudarthrosis	0

RESULTS

The patients were followed up at regular intervals i.e., every month during the first 3 months and every 3 months thereafter. The minimum follow up period was 6months and the maximum follow up period was 15 months. The mean follow up period in this study was 9 months.

The results were evaluated during follow up by taking into consideration the following factors:

1. Pain
2. Range of motion
3. Strength
4. Stability
5. Function
6. Reontgenographic documentation of fracture healing
7. Anatomic restoration

Constant score:

Constant and ***Murley's*** score was used to assess the functional outcome of these patients.[20,21,22,23]

The results were graded by using Neer 100 units rating system.

The rating system consists of

35 units for PAIN

30 units for FUNCTION

25 units for RANGE OF MOTION

10 units form ANATOMY

PAIN

Post op pain was recorded on a scale of 0-5 points, where points were given according to the following criteria

TABLE - XVI

PAIN SCALE	POINTS
No pain	5
Mild pain	4
Pain with unusual activity	3
Pain at rest	2
Marked pain	1
Complete disability	0

12 (60%) patients said that may had no pain and 5 (25%) patients had only mild pain,2 (10%) patients had pain after unusual activity and pain at rest in1 (5%) patients. No patient had disabling pain.

TABLE - XVII

S. NO.	PAIN	NO. OF PATIENTS
1	No pain	12
2	Mild pain	5
3	Pain with unusual activity	2
4	Pain at rest	1
5	Marked pain	0
6	Complete disability	0

FUNCTION

Function was evaluated with ability to perform day to day activities.

Points were according to the following scale.

4- normal

3-mild compromise

2-with difficulty

1-with aid

0-unable

NA-not available

Functional results were graded by following criteria.

Good functional result 3.5 – 4.0 paints

Fair 2.5 -3.4 points

Poor < 2.5 points

Twelve (60%) of the patients had good functional results, 8 (40%) had fair functional results and no patients had poor functional result.

FUNCTIONAL OUTCOME

TABLE - XVIII

S. NO.	FUNCTIONAL OUTCOME	NO. OF PATIENTS
1	Good	12
2	Fair	8
3	Poor	0

MUSCLE STRENGTH

Muscle strength was evaluated for the muscles around the shoulder and points allotted accorded to strength as follows:

Normal - 5

Against resistance - 4

Against gravity - 3

With elimination of gravity - 2

Flicker - 1

Paralysis - 0

Eighteen (90%) patients had normal muscle strength in all the muscle groups evaluated and one patient had good muscle strength and one patient had fair muscle strength.

TABLE - XIX

S. NO.	MUSCLE STRENGTH	NO. OF PATIENTS
1	Normal	18
2	Against resistance	1
3	Against gravity	1
4	With elimination of gravity	0
5	Flicker	0
6	Paralysis	0

RANGE OF MOTION:

ROM was evaluated during each follow-up and the improvement and progress recorded. The following table shows average ROM observed.

Shoulder joint**:** Active forward elevation was defined as the angle between the humerus and upper part of thorax in the sagittal plane. External rotation was measured with arm at patient side. Internal rotation was measured as the posterior segment that could be reached by the thumb with the elbow in a flexed position.

Elbow joint: Active flexion and extension were measured.

TABLE – XX

SHOULDER JOINT

S. NO.	MOTION	RANGE IN DEGREES	AVERAGE
1	Flexion	130-170	157.5
2	Abduction	140-170	159
3	ER	60-70	64.5
4	IR	60-70	65.5

TABLE – XXI

ELBOW JOINT

S. NO.	MOTION	RANGE IN DEGREES	AVERAGE
1	Flexion	120-130	127
2	Extension	0	0

OVER ALL RESULTS

The results were accorded to the following criteria:

Maximum No. points - 100

Excellent - 90-100

Satisfactory - 80-89

Unsatisfactory - 70-79

Failure - < 70

Of the twenty cases 16 (80%) patients had excellent result, 3(15%) satisfactory, and 1(5%) unsatisfactory results. There was no failures in our study. (TABLE- XXII)

TABLE - XXII

OVER ALL RESULTS

S. NO.	RATING	NO. OF PATIENTS	PERCENTAGE
1	Excellent	16	50
2	Satisfactory	3	15
3	Unsatisfactory	1	5
4	Failure	0	0

In our study internal fixation using locking compression plating techniques achieved union in nineteen of twenty fractures (95%). These results are comparable with those obtained by R Vander Griend et al open reduction and internal fixation using AO plating techniques (97%).

CASE ILLUSTRATIONS

CASE- I

NAME: MRS.PATTAMMA   I P NO: 872543

AGE / SEX: 68/F

DATE OF INJURY: 10.7.2006

DATE OF SURGERY: 14.7.2006

AO TYPE: B2.2

OSTEOPOROSIS INDEX (T-SCORE) : -2.8

ASSOCIATED INJURIES: NIL

PROCEDURE DONE: ORIF WITH LCP FIXATION

BONE GRAFTING: NIL

COMPLICATIONS: NIL

SECONDARY PROCEDURES: NIL

FUNCTIONAL OUTCOME:

TIME OF UNION	14weeks	
MOVEMENTS OF THE SHOULDER	ABDUCTION	160
	FLEXION	150
	INT.ROTATION	60
	EXT.ROTATION	70
MOVEMENTS OF THE ELBOW	FLEXION	130
	EXTENTION	0
PAIN IN THE SHOULDER	NO PAIN	

CASE ILLUSTRATIONS

CASE- II

NAME:MR.KUNJAPPAN IP NO:873634

AGE / SEX:61/M

DATE OF INJURY:19.7.2006

DATE OF SURGERY:25.7.2006

AO TYPE: A2.2

OSTEOPOROSIS INDEX(T-SCORE) : -2.6

ASSOCIATED INJURIES:NIL

PROCEDURE DONE:ORIF WITH LCP FIXATION

BONE GRAFTING:NIL

COMPLICATIONS:NIL

SECONDARY PROCEDURES:NIL

FUNCTIONAL OUTCOME:

TIME OF UNION	16weeks	
MOVEMENTS OF THE SHOULDER	ABDUCTION	150
	FLEXION	160
	INT.ROTATION	60
	EXT.ROTATION	70
MOVEMENTS OF THE ELBOW	FLEXION	130
	EXTENTION	0
PAIN IN THE SHOULDER	MILD PAIN	

CASE ILLUSTRATIONS

CASE- III

NAME:MRS.AMSAVENI IP NO:882160

AGE / SEX:53/F

DATE OF INJURY:01.08.2006

DATE OF SURGERY:05.08.2006

AO TYPE: A3.2

OSTEOPOROSIS INDEX(T-SCORE) : -2.5

ASSOCIATED INJURIES:FRACTURE DISTAL RADIUS

PROCEDURE DONE:ORIF WITH LCP FIXATION

BONE GRAFTING:DONE

COMPLICATIONS:NIL

SECONDARY PROCEDURES:NIL

FUNCTIONAL OUTCOME:

TIME OF UNION	24weeks	
MOVEMENTS OF THE SHOULDER	ABDUCTION	160
	FLEXION	170
	INT.ROTATION	60
	EXT.ROTATION	60
MOVEMENTS OF THE ELBOW	FLEXION	130
	EXTENTION	0
PAIN IN THE SHOULDER	MILD PAIN	

CASE ILLUSTRATIONS

CASE- IV

NAME: MRS.NAGAMANIAMMAL IP NO:871905

AGE / SEX: 65/F

DATE OF INJURY:12.08.2006

DATE OF SURGERY:16.08.2006

AO TYPE: B2.2

OSTEOPOROSIS INDEX(T-SCORE) : -2.9

ASSOCIATED INJURIES:NIL

PROCEDURE DONE:ORIF WITH LCP FIXATION

BONE GRAFTING:NIL

COMPLICATIONS:NIL

SECONDARY PROCEDURES:NIL

FUNCTIONAL OUTCOME:

TIME OF UNION	16weeks	
MOVEMENTS OF THE SHOULDER	ABDUCTION	160
	FLEXION	170
	INT.ROTATION	70
	EXT.ROTATION	60
MOVEMENTS OF THE ELBOW	FLEXION	130
	EXTENTION	0
PAIN IN THE SHOULDER	NO PAIN	

CASE ILLUSTRATIONS

CASE- V

NAME:MRS.AMIRTHAMMAL IP NO:882216

AGE / SEX: 83/F

DATE OF INJURY:02.09.2006

DATE OF SURGERY:07.09.2006

AO TYPE: A1.2

OSTEOPOROSIS INDEX(T SCORE): -3.0

ASSOCIATED INJURIES:FRACTURE BB FOREARM

PROCEDURE DONE:ORIF WITH LCP FIXATION

BONE GRAFTING:DONE

COMPLICATIONS:NIL

SECONDARY PROCEDURES:NIL

FUNCTIONAL OUTCOME:

TIME OF UNION	16weeks	
	ABDUCTION	150
	FLEXION	160
	INT.ROTATION	70
MOVEMENTS OF THE SHOULDER	EXT.ROTATION	60
	FLEXION	130
MOVEMENTS OF THE ELBOW	EXTENTION	0
PAIN IN THE SHOULDER	NO PAIN	

DISCUSSION

In this study we have analyzed 20 cases of fracture shaft of humerus with osteoporosis treated with Locking Compression Plate in our hospital.

There was female preponderance in our study 12 (60%) A study conducted by R. Ekholm et al involving 401 diaphyseal fractures there was a female preponderance.[77] Mc Cormack RG, Brain D et al involving 44 humeral shaft fractures there was a female preponderance. In Rose SH, Melton et al study of 586 humeral fractures there was a female preponderance.

In our study the average age of patients was 67.15 years which was comparable with the reports by R. Ekholm et al and J. Adami, J. Tidermarknd, K.Hansson, H. Tornkvist, S. Ponzer.

Free fall at ground level was the most common mode of injury & the average age of patient is 67.15 years in our study, much comparison with the Mc Cormack et al as fall on the arm was the predominant mode of injury & average age of the patient 64 years in their study. Since our women attain menopause early the osteoporotic changes are fast and have poor quality bone.

The OTA classification is the most widely used classification for humeral diaphyseal fractures. It has gained wide clinical acceptance by orthopaedic surgeons and radiologists is considered to have important implications for both treatment options and outcomes. Several authors have reported low level of inter- and intra observer reliability for subgroup classification.

In order to properly employ this classification, precise radiographic evaluation is of paramount importance. For the typical humeral shaft fracture it is rarely necessary to obtain further imaging. We have done bone densitometry study to assess the quality of bone. An exact assessment of the severity of osteoporosis in important in allowing adequate treatment for associated pain and for decreasing the risk of future osteoporosis related fractures. Computed tomographic scans of associated intra articular injuries proximally or distally, and also done in patients who had equivocal findings and also to find the direction of rotation.

There was a predominance of Type-A fractures in our study followed by Type-B and Type-C.

RATE AND TIME OF UNION:

The rate of union in Conservative methods (Functional cast bracing) is 97% -100%[12,73] and the union time is 11.5wks.[83]

Although faster union rate was noted when closed reduction was done rather than open reduction. Closed treatment of fracture is associated with moderate pain, poor motion and disability. Also 13% of patients treated by functional bracing end up with cosmetically unacceptable *angulation* of >15%,[49,50,83] whereas all operative procedures achieve good alignment of the fractured bone. *Non union* also occurs fairly commonly in conservative methods. Long time of immobilization due to conservative methods of treatment increases the rate of complications. Reintegration into the normal environment at home and securing the necessary support for the patient after release are significant aspects of treatment in order to make the dusk their life as active, enjoyable and social as possible.

Internal fixation in these conditions may relieve pain, protect adjacent soft tissues from further injury, prevent the so called fracture disease, and facilitate nursing and rehabilitation.

The rate of union in Intra medullary nailing technique is 80%-100%[13,18] and the union time is 18-24 weeks.[26,54,97] Although the nailing technique is simpler, lesser exposure and least damage to soft tissues nailing technique is associated with *nonunions, delayed union, impingement syndrome, injury to rotator cuff, shoulder instability and pseudarthrosis*.[35,59,61]

The rate of union in Plate osteosynthesis is 93% -100%[45,70,71,74] and the time of union is 4 – 6.7 months, and more than 90% united in 19 weeks.[82,87]

Vander Griend et al reported union in 35 of 36 plated humeral fractures with no shoulder or elbow morbidity and one temporary radial nerve palsy.[95]

Bell et al had similar results ie., union in 37 of 39 fractures.[9,98]

Tingstad et al had union in 78 of 83 fractures.

The union rate following open reduction and internal fixation of humeral shaft fractures averages 96% in number of large series.[36,63,66,94,95]

Complications are infrequent and include *radial nerve palsy* (2-5%) usually neuropraxic injuries which usually recover, *Infection* (1-2%) for closed fractures, 2% to 5% for open fractures and *refracture* is 1%.

We have seen few complications in our study two patients had superficial wound infection, and one patient had transient radial nerve palsy. Good functional results are seen reflecting the fact that radiological outcome may not imply functional outcome. There was no radiographic evidence non-union or deep infection in our study.

Finally a prolonged closely monitored and well defined program of rehabilitation was necessary to obtain the best functional results. Better results were obtained in more educated rehabilitation program with an active involvement of patient.[10,37]

We have followed the three phase rehabilitation protocol of ***Hughes and Neer*** in all our patients and this has provided good results. We had a full range of motion in shoulder and elbow joint in more than 90% of cases.

Plate fixation according to the ***Muller's technique*** is a reliable osteosynthesis method with few initial failures or malunions as evidenced by data in the literature. Infection is also rare. Although the radial nerve risk makes this technique rather difficult, excellent functional results can be achieved.

In our study internal fixation using locking compression plating techniques achieved union in 19 of 20 fractures (95%). These results are comparable with those obtained by R Vander Griend et al open reduction and internal fixation using AO plating techniques (97%).[80] The incidence of operative and post operative complications was low and the return of function was good except in patients with associated injuries.

The functional outcome of the patients were assessed by ***Constant and Murley's scoring system***. The score was more than 90%.

In summary fracture shaft of humerus in osteoporotic bones may be extremely demanding. There are many pitfalls for the unwary patient and surgeon to avoid during the course of treatment. Emphasis is placed on complete and accurate diagnosis and preoperative planning for formation of safe and simple techniques for restoration of disability, fracture healing and patient care, full range of motion and strength.

CONCLUSION

In Osteoporosis where early rehabilitation is the key ***Locking Compression Plate is ideal.***

In large bone Locking Compression Plate offers higher weight bearing capacity than the conventional plates.

An exact assessment of the severity of osteoporosis is important in allowing adequate treatment for associated pain and for decreasing the risk of future osteoporosis related fractures.

In osteoporosis or poor quality bone bicortical engagement is recommended.

Diaphyseal fractures of shaft of humerus in osteoporotic bone when treated surgically produce less pain, less stiffness and greater range of movement.

Earlier the surgery better will be the results.

In severely communited fractures where the anatomy cannot be restored without extensive soft tissue dissection, fixation with LCP gave better union and functional results.

Results are best when operative method results in stable fixation that allows early passive mobilization.

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CONSTANT SCORE TECHNIQUE

BACKROUND

THE **EUROPEAN SOCIETY FOR SHOULDER AND ELBOW SURGERY(ESSES)** adopted the scoring system of ***Constant and a Murley.*** This scoring system consists of four variables that are used to asses the function of the shoulder. The right and left shoulders are assessed separately.

The subjective variables are pain and ADL(sleep, work, recreation/sport) which give a total of 35 points. The objective variables are range of motion and strength which give a total of 65 points.

SUBJECTIVE

Pain	**15**
ADL(sleep,work,recreation/sport)	**20**

OBJECTIVE

Range of motion	**40**
Strength	**25**

PAIN

Pain	**Points**
None	**15**
Mild	**10**
Moderate	**5**
Severe	**0**

ACTIVITIES OF DAILY LIVING

Activity Level	Points
Full work	4
Full recreation/sport	4
Unaffected sleep	2

Positioning	Points
Upto waist	2
Upto xiphoid	4
Upto neck	6
Upto top of head	8
Above head	10

RANGE OF MOTION

Active range of motion should always be measured as a part of the constant score.

ESSES recommends measuring range of motion with the patient on a chair or bed, with weight even distributed between ischial tuberosities. No rotation of the upper body may take place during the examination.

In the case of active motion, the patient lift his arm to a pain free level. Note that the number of degrees at which the pain starts determines the range of motion. If one measures the active range of motion with pain, this should be stated. The Constant score cannot then be applied beyond the initiation of pain.

The most important thing is that range of motion is performed and measured in a standardized way.

In the constant score system there is a precise information about how the points are calculated. Bar in mind that 150 degrees of flexion give 8 points, while 151 degrees give 10 points.

Forward flexion 10 points	
0-30	0
31-60	2
61-90	4
91-120	6
121-150	8
151-180	10

Abduction 10 points	
0-30	0
31-60	2
61-90	4
91-120	6
121-150	8
151-180	10

External rotation 10 points (hand is not allowed to touch the head)

Not reaching the head	0
Hand behind head with elbow forward	2
Hand behind head with elbow back	4
Hand on top of head with elbow forward	6
Hand on top of head with elbow back	8
Full elevation from on top of head	10

Internal rotation-10 points	
End of the thumb to lateral thigh	0
End of the thumb to buttock	2
End of the thumb to lumbosacral junction	4
End of the thumb to L3(waist)	6
End of the thumb to T 12	8
End of the thumb to T 7(interscapular)	10

STRENGTH

Strength is given a maximum of 25 points in the constant score. The significant and technique of strength measurement has been, and continues to be, the subject of much discussion.

The European society for Shoulder and Elbow Surgery measures strength according to the following method.

A spring balance is attached distal on the forearm.

Strength is measured with the arm in 90 degrees of elevation in the plane of the scapula(30 degrees in front of the coronal plane)and elbow straight.

Palm of the hand facing the floor

The patient is asked to maintain this resisted elevation for 5 seconds

It is repeated three times immediately after another.

The average in pound (lb) is noted.

The measurement should be pain free. If pain is involved the patient gets 0 points.

If the patient is unable to achieve 90 degrees of elevation in the scapula plane the patient gets 0 points.

FUNCTION MUSCLE

0 Less than 1kg

3 “1kg – 2 kg”

5 “2kg – 3kg”

7 “3kg – 4kg”

9 “4kg – 5kg”

11 “5kg – 6kg”

13 “6kg – 7kg”

15 “7kg – 8kg”

17 “8kg – 9kg”

19 “9kg – 10kg”

21 “10kg – 11kg”

23 “11kg – 12kg”

25 “12kg or above”

SCORING

0-55	Poor
56-70	Moderate
71-85	Good
>86	Excellent

PROFORMA

CASE ILLUSTRATIONS

NAME: IP NO:

AGE / SEX:

DATE OF INJURY:

DATE OF SURGERY:

AO TYPE:

OSTEOPOROSIS INDEX (T-SCORE):

ASSOCIATED INJURIES:

PROCEDURE DONE:

BONE GRAFTING:

COMPLICATIONS:

SECONDARY PROCEDURES:

FUNCTIONAL OUTCOME:

TIME OF UNION		
MOVEMENTS OF THE SHOULDER	ABDUCTION	
	FLEXION	
	INT.ROTATION	
	EXT.ROTATION	
MOVEMENTS OF THE ELBOW	FLEXION	
	EXTENTION	
PAIN IN THE SHOULDER		