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Research Article

Results of Surgical Treatment of Intercondylar Fractures of the Humerus in Adults by Double Plate Technique

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Abstract

Introduction: Intercondylar humerus fractures pose a challenge in treatment, historically favoring non-operative approaches due to poor outcomes. Recent advancements, including improved understanding of elbow biomechanics, surgical techniques, fixation devices, and rehabilitation protocols, have shifted the paradigm. While open reduction and internal fixation are considered the gold standard for young patients, elderly individuals with poor bone quality may benefit from primary total elbow arthroplasty as a viable treatment option.

Aim of the work: This study aimed to evaluate the outcomes of open reduction and internal fixation using a double plate technique in treating displaced intercondylar fractures of the lower end of the humerus in adults.

Patients: Twenty patients with intercondylar humerus fractures underwent open reduction and internal fixation with a double plate technique. Predominantly male (60%) with a mean age of 41 years, patients were primarily heavy manual workers (45%). Road traffic accidents caused 60% of fractures. The mean time from injury to operation was 3±2.99 days, with an average operative time of 50.75±6.93 minutes. Notably, 20% of cases were open fractures, and 20% had associated injuries, primarily head injuries.

Methods: Comprehensive evaluation included history, clinical examination, and radiological assessments. Treatment involved initial first aid management, laboratory investigations, and open reduction with internal fixation under general anesthesia using the Bryan-Morrey posterior approach. Follow-up assessments were conducted clinically and radiologically.

Discussion: Surgical interventions yielded 90% satisfactory outcomes, with complications effectively managed. The study underscores the efficacy of modern surgical approaches in treating intercondylar humerus fractures.

Conclusion: Internal fixation with double plates effectively manages intercondylar fractures of the distal humerus, promoting satisfactory outcomes. However, complications such as elbow stiffness and heterotopic ossification may occur, necessitating vigilant management and follow-up.

Recommendation: Enlarging patient cohorts and extending follow-up periods are recommended to enhance statistical robustness and assess long-term outcomes thoroughly.Additionally, a comparative study evaluating primary total elbow replacement versus internal fixation in elderly patients with highly comminuted distal humerus fractures is proposed.

Introduction

Treatment of intercondylar fractures of the humerus is difficult and controversial. Prior to the last two decades the consensus favoured non-operative management because ofthe poor operative results. [1] In the last decade there has been advances in the understanding of elbow biomechanics, improvement in surgical techniques, new innovative fixation devices and postoperative rehabilitation protocols [2]. The principles set out by the Association for the Study of Internal Fixation (AO- ASIF), including anatomical articular reduction and rigid internal fixation, allow for healing and early postoperative range of motion. [2] In young patients, open reduction and internal fixation of distal humerus fractures using modern fixation principles are considered the gold standard. [2] In elderly patients, restoration of the anatomy and obtaining rigid internal fixation may be difficult because of poor bone quality and comminution of articular surfaces and metaphysis. In cases in which rigid internal fixation cannot be achieved to allow early range of motion, resultant prolonged immobilization often leads to poor outcome [2].Primary total elbow arthroplasty has evolved to become a treatment option for elderly patients with articular fragmentation, comminution, and osteoporotic bone [3].

Review of Literature

Anatomy

The lower end of the humerus presents articular and non articular portions. The articular portion takes part with the radius and ulna in formation of the elbow joint.The distal humeral shaft is triangular shapedin cross section; with its apex directed anteriorly. As the shaft approaches the distal humerus it bifurcates into two divergent cortical columns, termed the medial and lateral columns [4]. The medial column diverges 45 degrees from the humeral shaft in the coronal plane and termed as medial epicondyle [5]. The lateral column diverges at 20 degrees inthe coronal plane from the shaft. As it extends distally it curves anteriorly creating an angle of 35-40 degrees with the shaft in sagittal plane (Figure1-2) [6]. The lower end of the humerus is divided by a faint groove into a lateral convex surface termedthe capitellum, and medial pulley shaped surface termed trochlea. In the coronal plane, the trochela is more distal than the capitellum resulting in a valgus alignment of 4 to 8 degrees. At their most distal points, they are joined by the "tiearch," consisting of the articular segment - the trochlea and the capitellum [6]

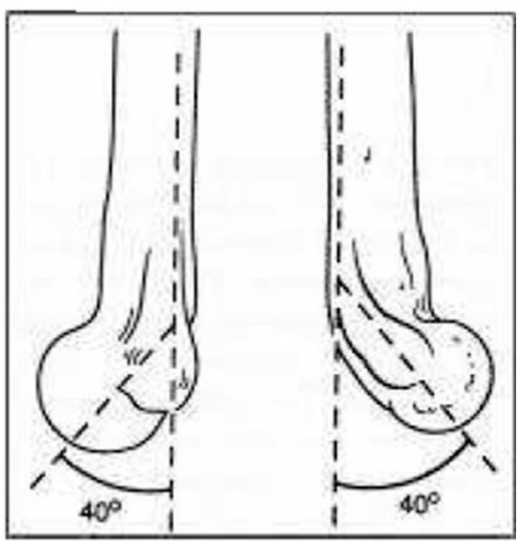

Figure 1: Configuration and angulations arounddistal humerus. [3]

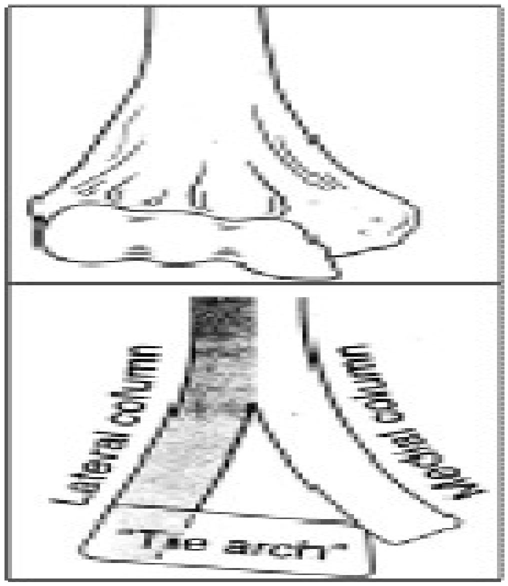

Figure 2: Columns of the distal end of humerusand tie arch [6]

The capitellum is a rounded, convex projection, considerably less than a half of a sphere which covers the anterior and inferior surfaces of the lateral part of the condyle of the humerus but doesn't extend on to its posterior surface. It articulates with the disk-like head of theradius, which lies in contact with its inferior surface in full extension of the elbow, but moves to its anterior surface when the elbow is flexed [7]. The trochela is a pulley shaped surface which covers the anterior, inferior and posterior surfaces of the condyle of the humerus. Its medial margin projectd downwards beyond the rest of thebone. It articulates with the trochlear notch of the ulna (Figure 3) [8].

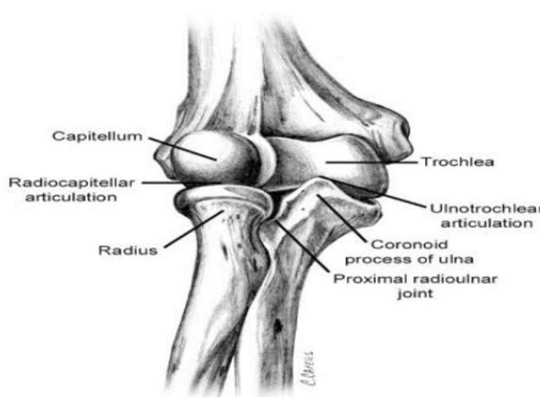

Figure 3: Bony anatomy of the elbow joint [4].

When the elbow is extended, the posterior and the inferior surfaces of the trochlea are in contact with the ulna, but as the joint is flexed the trochlear notch rolls forwards on to the anterior aspect and then the posterior aspect is then left uncovered [7]. The medial supracondylar crest is concave from behind and straight medially while lateral supracondylar crest is concave from behind and curved laterally. The medial epicondyle projects on the medial portion of the condyle. Its posterior surfaceis smooth and close to the ulnar nerve, which lies in a shallow groove as it descends down into the forearm. In this situation, the nerve can be felt androlled against the bone. The lower part of the anterior surface of the medial epicondyle shows an impression which gives attachment to the superficial group of the flexor muscles of the forearm [9,10]. The lateral epicondyle occupies the lateral part of the non-articular portion of the lower humerus, but doesn't project beyond the lateral supracondylar ridge. Its lateral and anterior surfaces show an impression which gives an attachment to the superficial group of extensor muscles of the forearm. Its posterior surface is slightly convex and can easily be felt through the skin at the back of the elbow [6]. The lateral border of the humerus terminatesat the lateral epicondyle and its lower portion is termed lateral supracondylar ridge. The medial border of the humerus terminates at the medial epicondyle and its lower portion is termed the medial supracondylar ridge [11]. Immediately above the trochlea on theposterior surface of the bone, a deep hollow is situated and is termed the olecranon fossa which lodges the tip of olecranon when the elbow isextended. A similar, but smaller hollow lies immediately above the trochlea on the anterior surface of the bone and is termed the coronoid fossa which lodges the coronoid process during flexion of the joint. The radial fossa is a very slight depression above the capitellum on the lateral side of the coronoid fossa, it is related to the margin of the radius in full flexion of the elbow [5]. The non-articular portion includes the medial and lateral epicondyles together with theolecranon, coronoid and radial fossae.

The Head of the Radius

It is a disc shaped structure , its upper surface is hollowed out to form a shallow cup for articulation with the capitellum of the humerus. Itscircumference is smooth and is deepest on the medial side where it articulates with the radial notch of the ulna [12].

The Upper End of the Ulna

It displays two substantial processes, the olecranon and the coronoid, and two articular areas, the trochlear and radial notches, which articulate with the humerus and radius respectively. The olecranon is the uppermost part of the bone , its anterior surface is smooth and articular and forms the upper part of the trochlear notch, while its posterior surface is triangular in outline. The coronoid process projects from the frontof the bone immediately below the olecranon. Its upper surface forms the lower part of the trochlearnotch and is therefore smooth and articular. The upper part of the lateral surface presents the shallow radial notch for articulation with the head of the radius. The trochlear notch articulates with the trochlea of the humerus, it is formed by the anterior surface of the olecranon and the superior surface of the coronoid processes. The bone is constricted at the junction of these two areas and they may be separated by a narrow strip. A smooth ridge which corresponds to the groove of the trochlea, divides the notch into a large medial and smaller lateral parts. The medial part conforms to the large flangeof the trochlea of the humerus [9,10,13,14]. The synovial membrane is attached to the articular margins of the joint and lines the capsule and annular ligament. The capsule attaches to the articular margin except at the coronoid, radial, and olecranon fossae, where it attaches to the rim of the fossae. The joint capsule does not attach to the radius; it isconfluent with the annular ligament that attachesto the anterior and posterior margins of the sigmoid notch and encircles the radius (Figure 4).

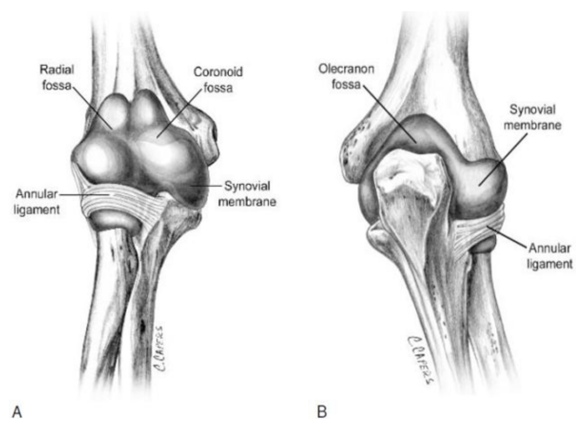

Figure 4: Elbow capsule and synovial reflections (A) anterior view (B) posteriorview [17].

Haversian fat pads are located in each of these fossae between the capsule and synovial membrane. Distention of the joint by hemarthrosis displaces these fat pads out of their respective fossae and produces the characteristic“fat pad sign” seen on lateral radiographs (Figure5) [15].

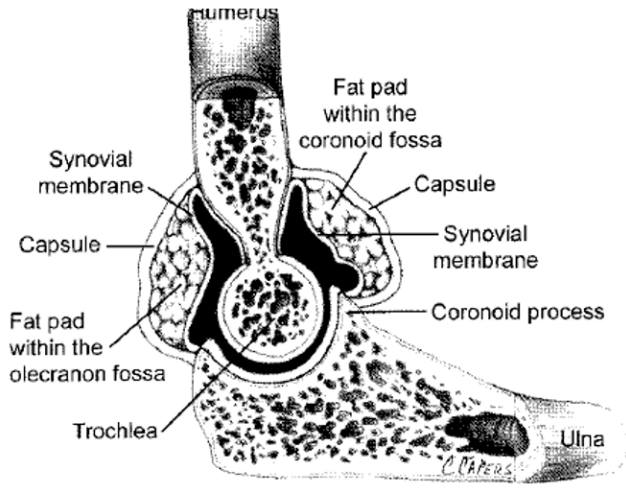

Figure 5: Sagittal view of the elbow showing intra-capsular extra-synovialHaversian fat pad [15].

The anterior capsule becomes taut in extension and is an important stabilizer of the extended elbow. The maximum joint capacity is 25 to 30 ml at approximately 80° of flexion [15].The ligamentous complexes that stabilize the joint are thickenings of the capsule on its medial and lateral aspects. The medial collateral ligament complexconsists of three components: the anterior and posterior bundles and the transverse ligament. The anterior bundle is structurally and biomechanically the significant component of the medial collateral ligament complex and has three functional bands. The first band arises from the anterior surface of the medial epicondyle and is taut in extreme joint positions. The second band arises from the tip of the epicondyle and is taut in intermediate joint positions. The third band, whicharises from the inferior edge of the epicondyle, is taut throughout the full range of joint motion (isometric). The anterior bundle attaches to the sublime tubercle on the medial aspect of the coronoid process. The posterior bundle (Bardinet's ligament) of the medial collateral ligament complex is fan shaped and attaches posterior to the axis of rotation on the medial epicondyle. It attaches to the middle of the medial margin of the trochlear notch and is taut during flexion. This ligament is important because it provides stability to the elbow against pronation. The transverse ligament of Cooper(olecranon-coronoid ligament) is not always well defined and does not contribute to joint stability because it is limited only to the ulna. The medial collateral ligament complexlies deep to the prominence of the medial epicondyle (Figure 6) [16,17].

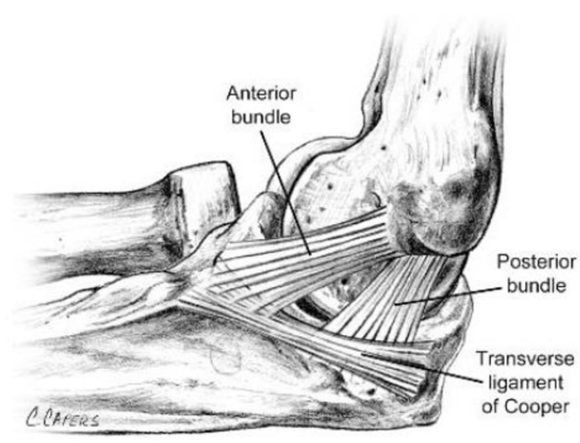

Figure 6: Medial ligament complex of the elbow [16].

The lateral ligament complex consists of four components: the radial collateral, the annular, the lateral ulnar collateral, and the accessory lateral collateral ligaments. The radial collateral ligament attaches to the lateral epicondyle and merges indistinguishably with the annular ligament. The annular ligament attaches to the anterior and posterior margins of the radial notch of the proximal ulna, encircling the radius but not attaching to it. The most distal part of the annular ligament has a smaller diameter that encircles the neck to provide greater stability (Figure 7).

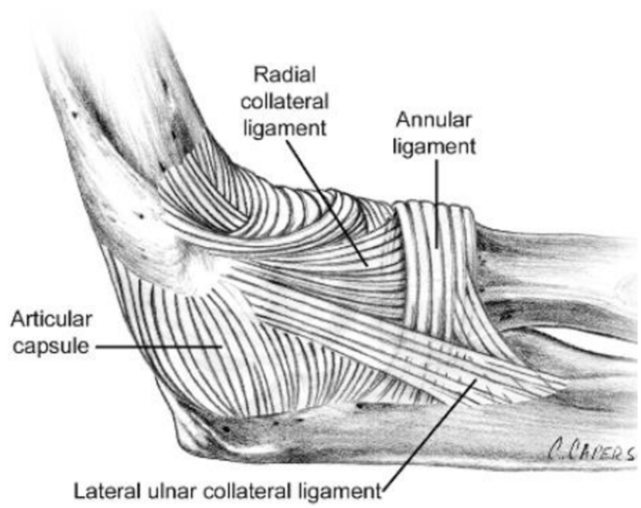

Figure 7: Articular capsule and its relation to annular ligament [15].

The lateral ulnar collateral ligament attaches proximally to the lateral epicondyle and distally to the tubercle of the supinator crest of the ulna. It is the primary lateral stabilizer of the ulnohumeral joint, and its deficiency is the "essential lesion" that produces posterolateral rotatory instability. The capsule posterior to this ligament is alsoimportant because it provides resistance against supination (Figure 8).

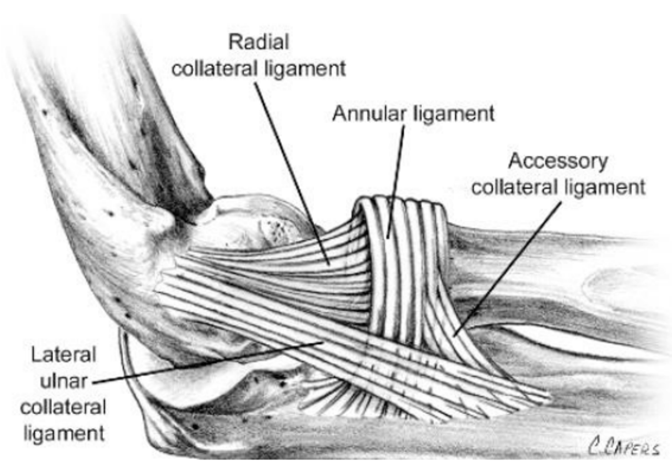

Figure 8: Lateral ligament complex of the elbow [18,19].

The accessory lateral collateral ligament blends proximally with the fibers of the annular ligament and distally attaches to the tubercle of the supinator crest. The function of the accessory ligament is to stabilize the annular ligament during varus stress [18,19]. The quadrate ligament of Denuce is a thin fibrous layer between the inferior margin of the annular ligament and the ulna. It is a stabilizer of the proximal radioulnar joint during full supination. The oblique ligament is a small and inconstant ligament formed by the fascia overlying the deep head of the supinator between the ulna and radius just below the radial tuberosity. It has no known functional importance,but some authors believe that this ligament is a cause of rotatory contractures of the forearm [19].

Blood Supply to the Elbow

There is a consistent blood supply to the elbow which can be divided into three vascular arcades: medial, lateral and posterior. The lateral arcade is formed by the interosseous recurrent, radial recurrent and radial collateral arteries and supplies the capitellum, radial head, lateral epicondyle and lateral aspect ofthe trochlea. The medial arcade is formed by the superior and inferior ulnar collateral and anterior and posterior ulnar recurrent arteries and supplies the medial epicondyle and the medial aspect of thetrochlea. The posterior arcade is formed by the medial collateral artery and contributions from themedial and lateral arcades and supplies the olecranon fossa and supracondylar area (Figure 9) [20].

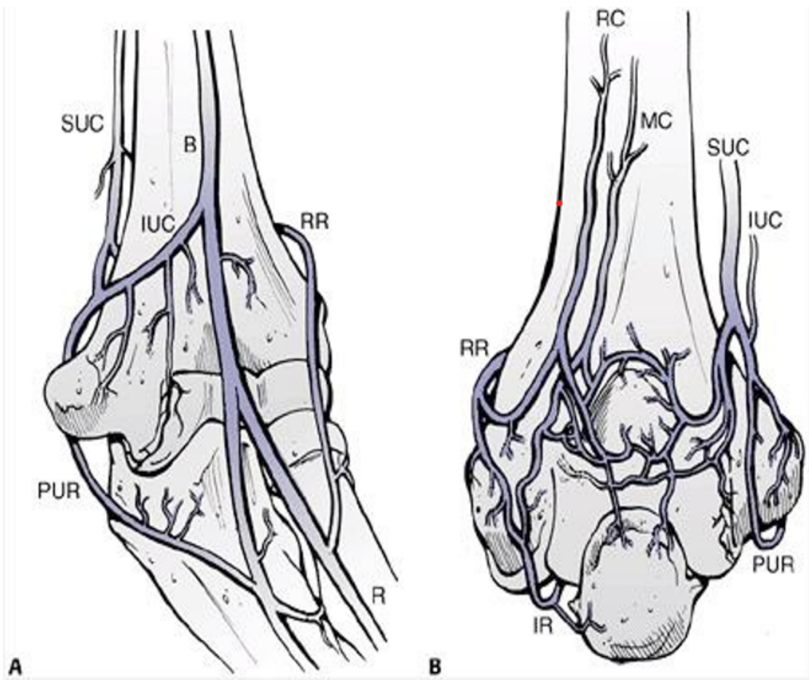

Figure 9: Vascular supply of distal end of the humerus (A).anterior view(B).posterior view [20].

SUC: Superior Ulnar Collateral IUC: Inferior Ulnar Collateral PUR: Posterior Ulnar Recurrent RR: Radial Recurrent RC: Radial Collateral IR: Interosseuos RecurrentMC: Medial Collateral

Biomechanics

The elbow-forearm complex represents a link in a mechanical chain of levers which begins at the shoulder and ends at the finger tips. Elbow motion serves to adjust the height and length of the limb to reach any point within the sphere made by shoulder motion [21]. The elbow is a compound joint with two degrees of freedom. The ulno-humeral part of articulation consisting of a hinge permitting one degree of freedom that is flexion-extension motionabout the transverse axis of the distal humerus. The second degree of freedom at the elbow is made by radio-humeral and radio-ulnar joints, thisarticulation allows rotation of the forearm arounda second longitudinal axis which is approximately perpendicular to the elbow axis and moves in the plane of flexion-extension. Partly because of the increased depth of the medial lip of the trochlea and partly because of theobliquity of the articular surface of the coronoid process which is not set at right angle to the shaft of ulna, an angle is made between the longitudinalaxis of the humerus and the extended fully supinated forearm. This angle is called the “carrying angle” and lies within the range of zero to twenty degrees of valgus with tendency towardsthe higher side of range in women (Figure10) [22].

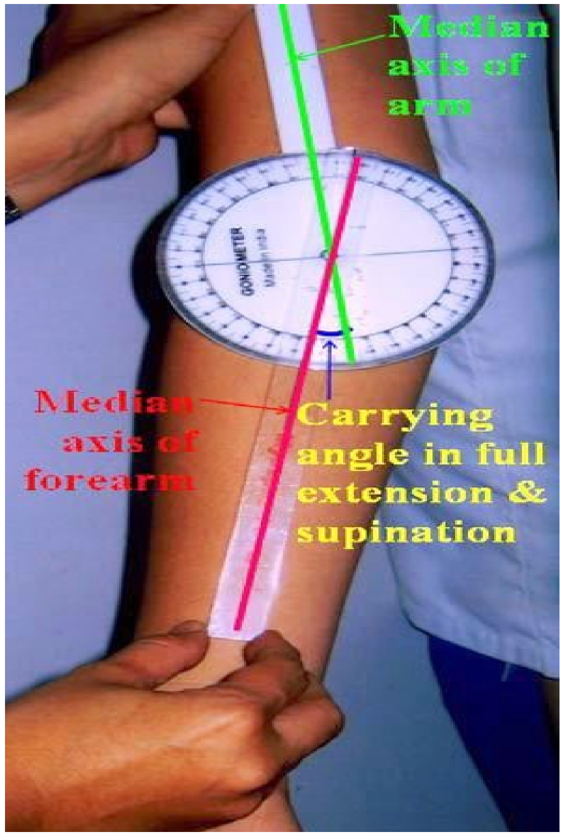

Figure 10: Measurement of the carrying angle [22].

Despite the deviation in extension, this angledisappears in flexion as the forearm and humerus become closely aligned and the hand lying in frontof the shoulder. Morrey and Chao reported that the long axisof the forearm changes linearly from valgus to slight varus during flexion; they also noted that the ulna and hence the entire forearm rotates aboutits long axis during flexion extension motion irrespective of the degree of supination or pronation [23]. An internal rotation of five degrees occurs during early flexion and an external rotation of five degrees occurs during terminal flexion, this probably due to the configuration of articular surfaces and ligaments. Flexion-extension capability of the elbow ranges from zero to one hundred and forty six degrees. This range of motion is limited at maximum extension of zero degree by:

1. The geometry of the joint surface and surrounding bones.
2. Passive supporting structures represented by collateral, capsular and other ligaments.
3. Active moving structures representedby muscles and tendons.

However, the limits for flexion depend on whether it is active or passive; the most important limitation for active flexion is the opponens of the contracted muscles of the arm with the forearm while other factors such as tension in the posteriorcapsular ligament and impact of coronoid process on the humerus are insignificant. As for passive flexion the anterior musclesof the forearm are flattened and other factors become more important i.e. the impact of radial head against the radial fossa, the coronoid process against the coronoid fossa, tension of the posteriorcapsular ligaments and tension developed passively in the triceps muscles. As regards rotation of the forearm, a movement which is produced by the radio-ulnar joints, it is basically produced by movements of the radius around the immobile ulna. The axis of this movement passes between the centre of the head of the radius and the base of the sytloid process of the ulna and when prolonged it passes near the little finger. It lies in line with the shaft ofthe humerus but oblique to the shaft of the ulna. Normal pronation is seventy-one degrees and supination is eighty-four degrees [24].

Muscle Function

The major flexors across the elbow joint are the brachialis, biceps brachii, brachioradialis, and extensor carpi radialis. The brachialis has the largest work capacity and potential contractile strength. It is active regardless the elbow position,type of contraction, or rate of movement, and the position of the shoulder does not affect these factors [25]. Major elbow extensors are the triceps,extensor carpi ulnaris, and anconeus. The triceps has the largest work capacity, and its medial head is the primary force producer. The position of the elbow affects the triceps; however, the position of the shoulder (excluding the long head) does not affect it. The anconeus is active in a variety of motions, so it is considered to be the dynamic stabilizer of the joint [26]. The muscles involved in pronation include the pronator quadratus and pronator teres. The primary pronator of the forearm is the pronator quadratus. The position of the elbow does not affect the pronator quadratus. The pronator teres functions as a secondary pronator during rapid pronation or during pronation against resistance [25]. The muscles involved in supination of the forearm are the supinator and the biceps. Supination is achieved primarily by the supinator muscle, with the biceps acting in a secondary role.The supinator acts independently during slow, unrestrained supination. During restrained or rapidsupination or resisted supination in any position, the biceps assists the supinator muscle. When the biceps assists supination, the extensors must act antagonistically to cancel any flexion that the activity of the biceps creates, resisting varus stress, valgus stress, and joint distraction in extended and 90° flexed positions. In the flexed position, the medial collateral ligament provides 55% of the varus torque neededto resist the valgus stress.

The soft tissues and capsule provide 11% of the resistance to valgus stress, and osseous articulation providesapproximately 34% of this valgus resistance. In the extended position, the medial collateral ligament provides 31% of the resistance to valgus stress, with the capsule and joint articulation providing 38% and 31%, respectively. The lateral collateral ligament, anconeus, and joint capsule provided stability for resisting varus stress. At 90° of flexion, the lateral collateral ligament contributes 10% of the valgus torque needed to resist varus stress, and the joint articulation and joint capsule provide 75%and 15%, respectively. In the extended position, joint articulation provides 55% of the resistance to varus stress, and the lateral collateral ligament andjoint capsule provide14% and 31%, respectively. Resistance to joint distraction is dependent on the position of the elbow. At 90° of flexion, themedial collateral ligament primarily provides 78%of the resistance to distraction. The lateral collateral ligament contributes 12%, and the joint capsule provides 10%. In the extended position, the contribution to distraction resistance is reversed; the joint capsule provides 85% of the resistance, and the lateral andmedial collateral ligaments provide 7% and 8%, respectively [27].

Classification

Several classification systems for intra-articular both column fractures of the distal humerus have been proposed.

In 1936, Reich first described “T” and “Y” intercondylar fractures [28].

In 1969, Riseborough and Radin (Figure11) [29]described 4 types of intercondylar “T-type”distal humerus fractures:

- Type 1: Non-displaced fracture,
- Type 2: Displaced but withoutrotation of the fragments,
- Type 3: Includes fragment rotation,
- Type 4: Involves severecomminution.

Although initially relevant for its descriptivevalue, these classifications proved inadequate in reliably describing the fracture and directing treatment as these injuries were more frequently treated operatively.

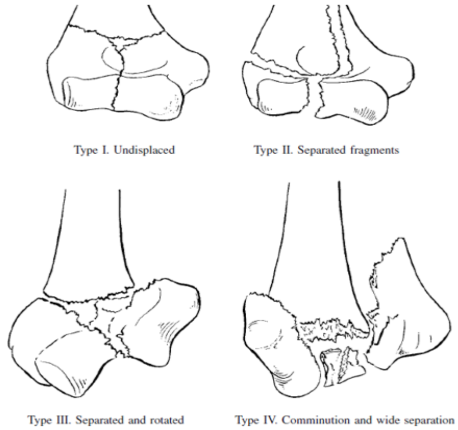

Figure 11: Riseborough and Radin classification of the distal humerus fractures [29].

The Orthopaedic TraumaAssociation's(OTA) alpha-numeric system [30], based on the comprehensive classification of fractures of long bones, assigned three main types:

- Type A: Extra-articular.
- Type B: Partial articular.
- Type C: Complete articular.

Sub-types were given thereafter for further fracture details. Although useful for cataloging fractures for research purposes, the clinical application of the system is limited and hindered by poor inter-observer reliability beyond identification of the basic three types (Figure 12).

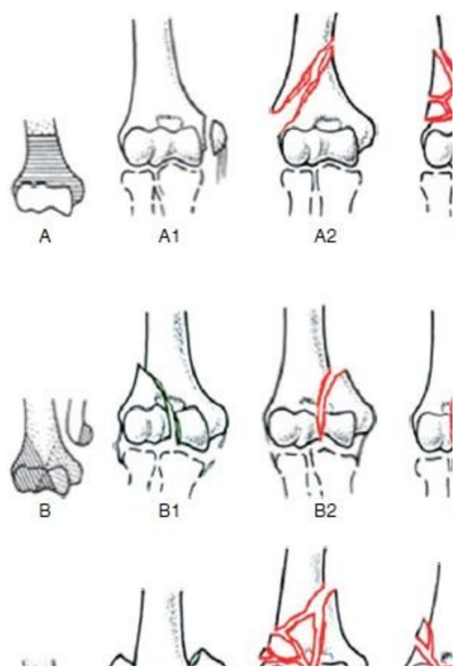

Figure 12: The AO classifications of the distal humerus fractures [30].

Jupiter and Mehne [31], developed a different comprehensive system based on the surgical anatomy and the techniques used for reconstruction. There are three basic categories as follows (Figure 13):

Grade I: Intra-articular fractures subdivided into: A: Single column. B: Bicolumnar. C:Capitellar. D: Trochlear.

Grade II: Extra-articular, intra-capsularfractures.

Grade III: Extra-capsular fracturessubdivided into: A: Medial epicondylar. B: Lateralepicondylar.

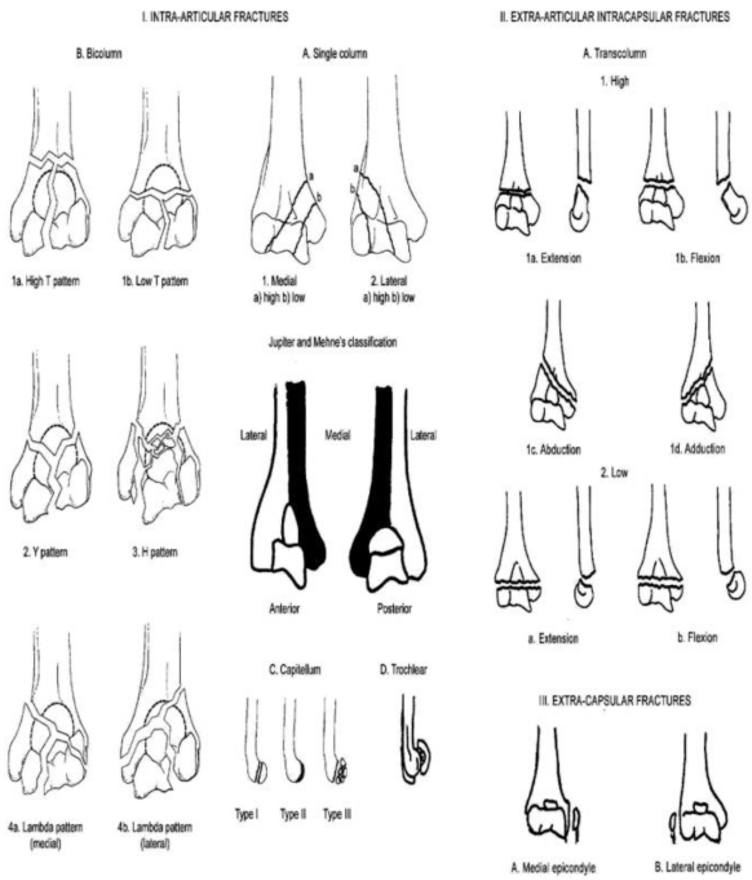

Figure 13: Summary of the Jupiter and Mehne system for the classification of distal humeral fractures [31].

Epidemiology/Mechanism of Injury

Distal humerus fractures represent 2% of all fractures and approximately 30% of those involving the humerus [32]. A population-based study examining all patients presenting to a single center identified a bimodal distribution with peak occurrences in young males (12-19 years) and elderly females (80 years). Robinson et al, identified an incidence of 5.7 of 100,000 in the population per year with a nearly equivalent male-to-female ratio [33]. Over 25-year period, the incidence of distal humerus fractures among patients older than 60 years of age nearly tripled (11-30%). Furthermore,the incidence in 2030 is projected to be 52 of 100,000 [33] Motorized vehicles and extreme sports contribute to the severity and incidence of distal humerus fractures in the young. By contrast, elderly patients generally present following a low-energy ground level fall [34]. Mechanism of injury of this fracture is probably caused by the impact of the ulna in the trochlear groove, forcing the condyles of the distalhumerus apart. The injury may occurs in either flexion or extention. In flexion type injury, Palmar (1961) has speculated that the elbow against the posterior elbow (olecranon) coupled with contraction of the forearm muscles, produce the fracture with less force than expected. In many instances, however, the forces applied to the posterior flexed elbow areviolent, as in road traffic accident. In flexion type fracture, the condyles are usually found anterior tothe humeral shaft.

In the extention type fracture the condyles are usually found to lie posterior the humeral shaft. In the extention type injury, the ulna is directed anteriorly against the posterior aspect of the trochela, separating the condyles at the same time as supracondylar portion is fractured [35].

Modalities of Management

Closed techniques

a) Cast immobilization: this involves closed manipulation and immobilization in cast. This management represents the worst, due to inadequate reduction and prolonged immobilization [36].

b) Traction: Most popular of the closed technique used only in severe comminuted injury. The commonest method is the overhead olecranon pin traction. This method is very cumbersome and requiresprolonged stay in the hospital .Accurate reduction is not possible and reported methods are inconsistent. Only very small series are documented supporting this method [37] (Figure14).

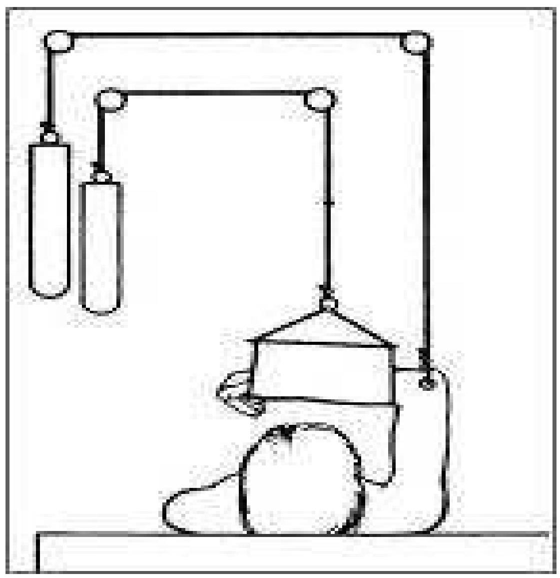

Figure 14: Over head olecranon pin traction [37].

c) Bag of bones technique: promoted by Eastwood-Hugh Owen Thomas. The arm is placed in a cuff & collar sling with elbow in as much flexion as possible. The elbow is left hanging free and early mobilization of hand, shoulder and elbow is encouraged [38].

Open Reduction and Internal Fixation:

The goal of operative treatment is to restore elbow function by obtaining anatomic and stable reduction of the articular surface. Central to this goalis rigid fixation of the anatomic surface so that earlymotion may be instituted. Partial articular fractureswith large fragments can be fixed directly using thelag technique to the intact medial or lateral column.Complete articular fractures are managed by converting them to a partial injury by quickly restoring one column. Thereafter, remaining fragments are fixed to the stabilized column. Alternatively or in conjunction with this method offixation, 1 or 2 screwscan be directed along the axisof elbow rotation through the trochlea and capitellum. Whenever possible, these screws shouldbe passed through contoured plates to provide additional stability. Inter-fragmentary compressionshould be used with caution in the presence of articular comminution where the articular surface may be inadvertently shortened or deformed resultingin restriction of ulno-humeral motion. In addition, osteochondral fragments should be retained wheneverpossible and secured with buried implants; such ascountersunk mini-fragment screws, headless variable pitch screws, or small threaded K-wires. Screw fixation alone is seldom adequate toprovide the typeof rigid fixation needed topermit early motion. Platefixation of the distal humerus has traditionally involved two orthogonal plates, as described by theAO-ASIF group [39]. One plate is placed along the posterolateral aspect of the distal humerus along thelateral column and capitellum. The second plate isplaced medially and is contoured around the medialcolumn. In cases with significant comminution or osteoporosis a third plate can be applied posteriorlyalong the lateral column for additional fixation [40]. Locking compression plates offer improved stabilityin areas where screw purchase may be tenuous.

Locked plates have been shown to provide a marked increase in resistance to bending, torsion, and axialcompression loading among distal humerus fracturesas compared to standard fixation with traditional non-locking plates [41]. O'Driscoll recently defined principles of fixation of distal humerus fractures using parallel locking pre-contoured plates and defined two goals that should be met: First, fixationwithin the distal fragment must be maximized, andsecond, all fixation in distal fragments should contribute to stability between the distal fragments and the shaft [42].

In addition, he defined eight technical objectives by which these principles are met:

1. Every screw in the distal fragments shouldpass through a plate.
2. Every screw should engage a fragment on theopposite side that is also fixed to a plate.
3. As many screws as possible should be placedin the distal fragments.
4. Each screw should be as long as possible.
5. Each screw should engage as many articular fragments as possible.
6. The screws in the distal fragments should lock together by inter-digitation, creating a fixed- angle structure.
7. Plates should be applied such that compressionis achieved at the supracondylar level for both columns.
8. The plates must be strong enough and stiff enough to resist breaking or bending before union occurs at the supracondylar level.

These principles can be achieved using parallel plates. Linking the plates together throughthe bone with screws, thereby creating the architectural equivalent of an arch, offers the greatest biomechanical stability for comminuted distal humeral fractures [43]. The arch is formed by inter-digitation of locking screws passing through the distal fragments from both plates in the sagittalplane. In cases involving significant metaphyseal comminution, two treatment options exist. The first is to resect the comminution and shorten the distal humerus to achieve contact, compression, and union [44]. The second option is to bridge the comminution with longer plates. The rich blood supply around the humerus facilitates healing when stable fixation is achieved proximally and distally to the comminution. The addition of bone graft can also augment healing.

Total Elbow Arthroplasty

In cases of highly comminuted articular fractures in a low demand, osteoporotic elderly patients or fractures occuring in elbow with pre- existing inflammatory joint destruction, the experienced surgeon may decide that the distalhumerus is not reconstructable. Total Elbow Arthroplasty (TEA) using a semiconstrained prosthesis has been shown in several studies to be effective primary treatment, at least in the short term. The disadvantages of total elbow arthroplasty for acute fractures include the functional restrictions imposed upon the patient, the risk of serious complications such as infection,and the potential for failure of prosthetic articulations with the possible need for revision. Infirmity and activity level are used rather than age when considering total elbow arthroplasty for fracture treatment [45,46].

Complications

Complications are common in the management of distal humerus fractures and include elbow stiffness, heterotopic ossification, nonunion, neuropathies, and infection. Post-traumatic elbow stiffness can arise from both intrinsic and extrinsic sources. Intrinsic causes of stiffness include joint adhesions, synovitis, articular incongruity, and intra-articular loose bodies. Extrinsic causes include capsular contractures and heterotopic ossification. Loss of some motion is expected after distal humerus fractures, particularly terminal extension. Loss of flexion is less tolerated than loss of extension. Although functional range of motion has been defined as 30 to 130 degrees of flexion, even small decreases in motion can cause functional impairment depending upon the patient's needs. Post-traumatic elbow stiffness is best managed by avoidance and diligent post-operative rehabilitation. During the early post-operative period motion should be instituted and edema minimized.Also, splinting in full extension will tension the anterior capsule, compress posterior structures, and relax the ulnar nerve. Lack of progression in motion over the first 3 post-operative months warrants more aggressive modalities including serial casting and static progressive splinting. If non-operative methods fail to restore motion, patients can be considered for surgical release. Both open and arthroscopic techniques have proven successful in restoring motion [47]. Heterotopic ossification is common after distal humerus fractures. Susceptible patients include those with brain or spinal cord injury, severe trauma or open injuries, and a history of prior heterotopic ossification. Such patients shouldreceive prophylaxis against heterotopicossification such as Indomethacine . Up to 3% of patients with local injury to the elbow develop heterotopic ossification but in most cases do not cause functional impairment.

Traditionally, the teaching has been to wait until complete radiographic maturation of the heterotopic bone, typically 12 to 18 months, before attempting excision. However, the recurrence rate after early excision, such as 3 to 6 months post-operatively, combined with external beam radiation has been shown to be no higher than that for delayed excision and as such is becoming the favored approach [48]. Early excision also provides the advantage of minimizing capsular and ligamentous contracture, muscular atrophy, and articular degeneration from restricted motion [47]. Nonunion occurs in 2 to 10% of distal humerus fractures treated with open reduction internal fixation [49]. Risk factors include comminution, bone loss, and inadequate fixation. Treatment options include revision of open reduction and internal fixation with bone graft or total elbow arthroplastyin older low-demand patients with poor bone stock [49,50]. Neuropathy, particularly of the ulnar nerve,may occur from the initial injury, iatrogenically during surgery, or secondarily from post-operativescarring. Release and subcutaneous transposition of the ulnar nerve at the time of surgery reduces the risk of future neuropathy. Despite adequate release and transposition, irritation and transient sensory changes have occurred in up to 50% of patients in some series [51-53]. McKee et al, found that neurolysis and transposition resulted in significant symptomatic relief and functional improvement for patients with post-operativeulnar neuropathy [54]. However, improvement in motor strength is often incomplete and may take several years.

Deep infection is uncommon occurring on an average of 3% of patients. Risk factors include open fractures with massive contamination and devascularized segments of bone and soft tissues. Urgent debridement is mandatory. In refractory cases and those with failure of fixation, removal of implant is required [55].

Other significant complications associatedwith these fractures include joint osteoarthrosis, complications related to olecranon osteotomy including non-union, heterotropic ossification, hardware removal for prominence, avascular necrosis, and elbow instability [47].

Aim of the Work

The aim of this work was to study the resultsof treatment of displaced intercondylar fractures of the lower end of the humerus in adults by open reduction and internal fixation using double plate technique.

Patients

The study included randomly collected 20 patients with intercondylar fractures of distal end humerus, treated by open reduction and internal fixation by double plate technique in El-Hadara University Hospital from January 2011 to July 2012.

Sex

The study included 12 males (60%) and 8 females (40%). (Figure16)

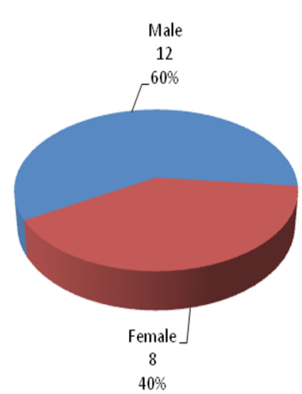

Figure 16: Distribution of studied cases according to sex.

Full preoperative assessment includingclinical and radiological examination with routine investigations were done for every patient.

Age

The age of the patients included in the studyranged from 18 to 70 years with a mean age of 41 years. (Table 1) (Figure 15).

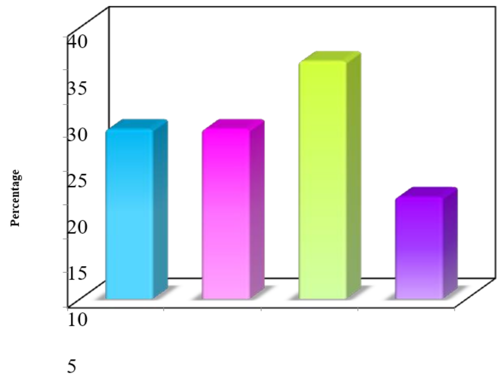

Figure 15: Distribution of studied casesaccording to age

Age	No	%
<30	5	25.0
<40	5	25.0
<50	7	35.0
50 or more	3	15.0
Min. – Max.	18.0 – 70.0	
Mean ± SD	40.70 ± 13.61	
Median	41.0	

Table 1: Distribution of the studied casesaccording to age.

Occupation

Heavy manual workers as farmers, construction workers etc. were 9 patients (45%), while 11 patients (55%) were adopting sedentary work. (Figure17).

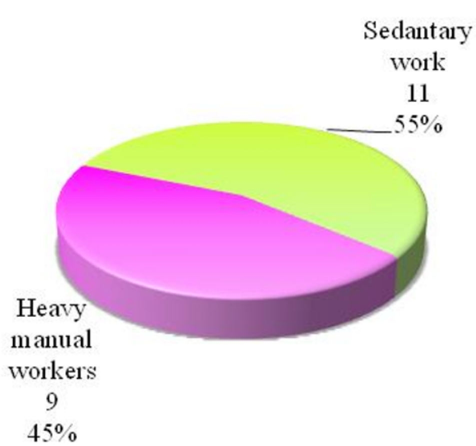

Figure 17: Distribution of studied casesaccording to occupation.

Occupation	No	%
Heavy manual workers	9	45.0
Sedantary work	11	55.0

0 <30 < 40 < 50 50 or more Age

Table 2: Distribution of the studied cases according to occupation.

Medical history

One patient was diabetic and hypertensive, one patient was hypertensive and one patient had ischemic heart disease.

Side

The study included 13 patients presented with right side fracture distal humerus, 7 patients presented with left side fracture and no cases presented with bilateral fracture. (Table3) (Figure18).

Side affected	No	%
Right	13	65.0
Left	7	35.0

Table 3: Distribution of the studied casesaccording to side affected

Figure 18: Distribution of studied casesaccording to side affected.

Dominant side

18 patient were right handed and only 2 cases were left handed, one of them had fracture in left side distal humerus (Table 4).

Dominant side	No	%
Right	18	90.0
Left	2	10.0

Table 4: Distribution of the studied casesaccording to dominant side

Mechanism of injury

Road Traffic Accident (RTA) was the responsible mechanism in 12 patients (60%), simple fall on elbow in 7 patients (35%) and fall from height in one patient (5%). (Table 5) (Figure19).

Mechanism of injury	No	%
RTA	12	60.0
Simple fall on elbow	7	35.0
Falling from height	1	5.0

Table 5: Distribution of the studied cases according to mechanism of injury

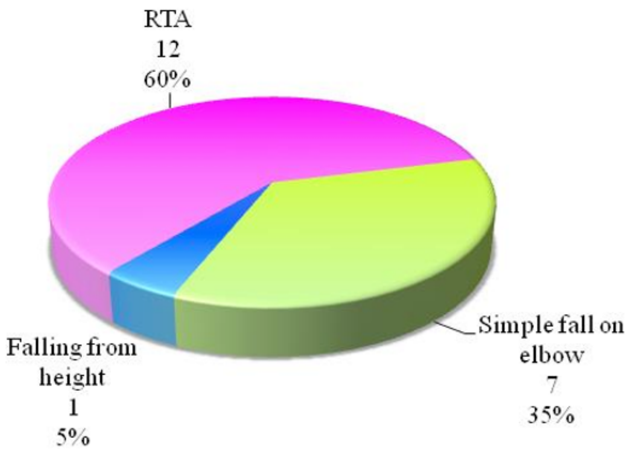

Figure 19: Distribution of the studied casesaccording to mechanism of injury.

Fracture Type

Adopting AO classification, there were 3patients with C1 fracture type, 8 patients presentedwith C2 fracture type , 9 patients with C3 fracture type (Table 6).

AO Fracture Type	**No**	**%**
C1	3	15.0
C2	8	40.0
C3	9	45.0

Table 6: Distribution of the studied cases according to fractureclassification.

Open Fractures

Only 4 cases were open fractures (20%). Three of them were open grade one (G I) and one was open grade two (G II). (Table 7) (Figure 20).

Open or closed	No	%
Closed	16	80.0
Open	4	20.0

Table 7: Distribution of the studied cases according to whether open or closed.

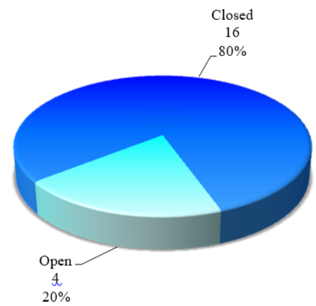

Figure 20: Distribution of the studiedcases according to whether open or closed.

Associated injuries

We had 4 cases with associated injures (20%).Three patients had head injury (15%), one of themhad ribs and patella fractures and was admitted to ICU and another one had calcaneus fracture (5%). One patient had fracture distal end radius (5%).(Table 8) (Figure 21).

Associated injuries	No	%
Absent	**16**	**80.0**
Present	**4**	**20.0**
Head injuries	1	15.0
Head injury + Patella, ribsfractures	1	5.0
Distal radius fracture	1	5.0
Head injury+ Calcaneusfracture	1	5.0

Table 8: Distribution of the studied casesaccording to associated injuries

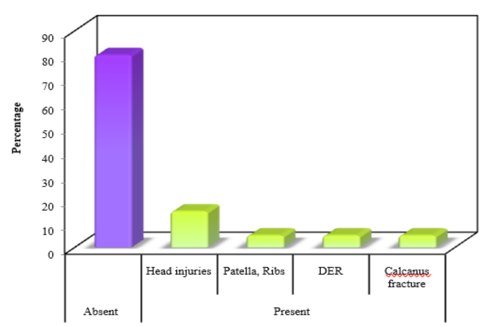

Figure 21: Distribution of the studiedcases according to associated injuries.

Time Lapse between Injury AndOperation

It ranged from 1 day to 14 days with a meantime 3± 2.99 days.(Table 9)

Time laps (days)	No	%
1 – 2	12	60.0
3 – 4	6	30.0
5+	2	10.0
Min. – Max.	1.0 – 14.0	
Mean ± SD	3.0 ± 2.99	
Median	2.0	

Table 9: Distribution of the studied cases according to time lapse before operation

Operative Time

It ranged from 40 till 70 minutes with a meanoperative time 50.75± 6.93 minutes.

Operative time (minutes)	No	%
<50	5	25.0
>50	15	75.0
Min. – Max.	40.0 – 70.0	
Mean ± SD	50.75 ± 6.93	
Median	50.0	

Table 10: Distribution of the studied cases according to Operative time.

Methods

Patients were be examined according to aspecial sheet [56]

I. Methods of diagnosis:

(A) History:

- Name
- Sex
- Age
- Address
- Occupation
- Date of admission
- Side affected
- Mechanism of injury
- First aid treatment
- Time elapsed between trauma and admissionto the hospital

(B) Clinical Examination:

- General examination: included evaluation ofthe general condition of the patient.
- Local examination:
- Swelling
- Deformity

- Skin condition
- Tenderness
- Associated injury
- Neurovascular complications

(C) Radiological examination:

1. Plain x-ray anteroposterior and lateral projections of the elbow had been done to assess the type of the intercondylar fractures.
2. CT when indicated.

II. Methods of treatment

(A) First aid management

- Care of the general condition and associatedinjuries.
- Immediate debridement of wounds in openfractures.
- Above elbow slab was applied initially forimmobilization.
- All patients with open fractures receivedprophylactic antibiotics.
- As soon as their general condition permitted,patients were prepared for internal fixation
- Laboratory investigations:
- Full laboratory investigations were done for every patient including:
- Complete blood picture.
- Fasting blood sugar.
- Bleeding and clotting time.
- Blood urea and creatinine.
- Liver enzymes

(B) Open Reduction and internal Fixation

1. Anesthesia and position of the patient:

Under general anesthesia, with the patient inthe prone position, with the elbow was flexed at right angle over an arm board to allow free movement of the elbow. A pneumatic tourniquet was applied in 10 cases and deflated after 60–90 minutes to minimize the chances of tourniquet palsies.

2. Exposure:

The posterior approach (Bryan-MorreyApproach [57] was done.

- A straight posterior incision in the midline of the limb extending from 7 cm distal to thetip of the olecranon to 9 cm proximal to it. the ulnar nerve was identified proximally atthe medial border of the medial head of the triceps, and dissected free from its tunnel distally to its first motor branch
- The medial aspect of the triceps was elevated from the humerus, along the intermuscular septum, to the level of theposterior

capsule.

- The superficial fascia of the forearm wasincised distally for about 6 cm to the periosteum of the medial aspect of the olecranon.

- The periosteum and fascia were carefully reflected as a single unit medially to laterally .The medial part of the junction between the triceps insertion and the superficial fascia and the periosteum of the

- a were the weakest portion of the reflected tissue. Care was taken to maintaincontinuity of the triceps mechanism at this point; the triceps tendon was carefully dissected from the olecranon when the elbow was extended to 20 to 30 degrees to relieve tension on the tissues, and then the remaining portion of the triceps mechanismwas reflected .

- To expose the radial head, the anconeus wasreflected subperiosteally from the proximal ulna; the entire joint was widely exposed .

- The posterior capsule usually was reflected with the triceps mechanism, and the tip of the olecranon was be resected to expose thetrochlea clearly.

- During closure, the medial collateral ligament was carefully repaired if itsrelease was necessary.

- The triceps was returned to its anatomicalposition and sutured directly to the bone through holes drilled in the proximal aspectof the ulna.

- The wound was closed in layers, and aradyvac was put in the wound.

- This exposure permited good exposure of the distal humerus by reflecting the triceps tendon and its insertion from medial to lateral. The reflected triceps tendon maintained its attachment to the ulnar periosteum and anconeus thereby preserving its length. The main advantage of this approach was that it avoided the complications associated with an olecranon osteotomy. Identification of ulnar nerve at the time of surgery is important to prevent its injury [58-60].

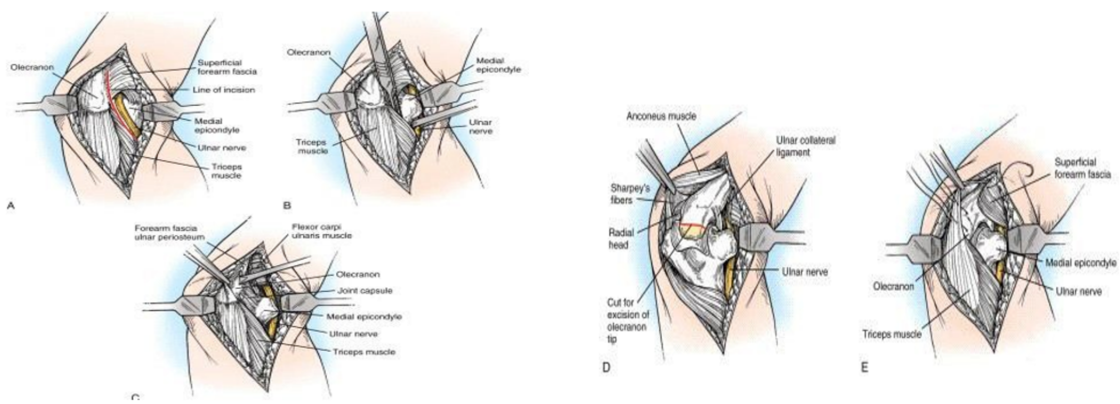

Figure 22: Bryan-Morrey extended posteriorApproach of the elbow [60].

3. Reduction and fixation of the fracture:

Articular Reconstruction

The principlesof peri-articular fracture fixation include restoration of the articular segment, column realignment and rigid fixation to allow for early mobilization. Preliminary fixation of the articular segment was performed with Kirschner wires (K- wires) .Several K-wires were required for temporary fixation, therefore, they were placed strategically taken in to consideration final plate and screw position. The main fragments of the articular segment were fixated by 2 methods. The first method was the placement of a central screw down the axis of the trochlea to fixate the 2 main fragments. Another method was provisional fixation of the articular segment with K-wires followed by definitive fixation with screws placed through medial and lateral plates applied in a parallel manner .In cases with articular comminution, the comminuted minor fragmentswere fixated to the major fragments with threaded K-wires or headless compression screws [61].

Column Reconstruction

Once the articular segment has been provisionally fixed, it was rigidly linked to the humeral diaphysis. Provisional fixation of the articular segment to the diaphysis was performed with K-wires inserted retrograde from distal to proximal. Several different plating techniques exist, including orthogonal plating (90:90) which was used in this study. Following surgery the elbow was placed through a range-of motion to ensure there is no impingement, hardware prominence or instability. Intraoperative fluoroscopy was done to ensure all hardware wasextra-articular [62].

Plating Technique

Orthogonal Plating (90:90)

The AO group has recommended an orthogonal (perpendicular or 90/90) plate configuration to maximize stability and allow early mobilization [63,64]. Internal fixation was done using double plates one of them was 3.5mm reconstruction plate medially applied and the other was 3.5mm reconstruction plate posterolaterally applied. The wound was closed and the limb immobilized in a plaster splint and sling, the elbow was flexed at 90degrees and the forearm in mid-position. for the first two weeks. A check x-ray was done post-operatively. After two weeks the stitches were removed.

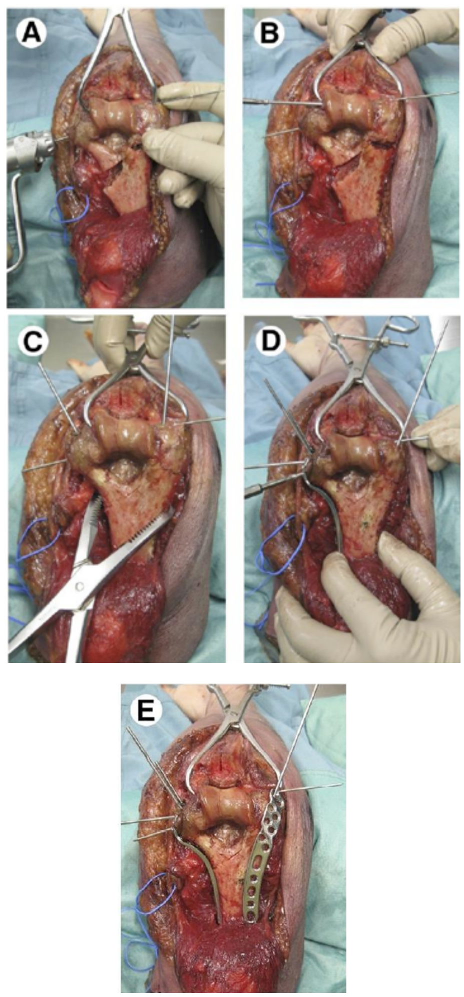

Figure 23: Posterior approach isrecommended for open reduction and internal fixation of distal humerus fractures. After exposure of the distal humerus,Steps of openreduction and internal fixation [64].

C. Rehabilitation and Outcome

Early postoperative rehabilitation was recommended to avoid the formation of intra- articular adhesions and peri-articular fibrosis that would make the elbow stiff. Aitken et al in their retrospective study concluded that the most important indicator of end result was the starting point of physiotherapy [65]. After the postoperative pain has subsided in about two days except in two cases which had sever comminuted fractures with suboptimal reduction one of them started elbow motion after one week and the other started after 12 days , active and active assisted range of motion for elbow flexion/ extension and supination/pronationstarted. This is initially started in horizontal plane to eliminate the effect of gravity. No passive flexion was allowed at this time and up to 6 weeksto allow fracture healing and reduce chances of heterotopic bone formation. Passive gravity assisted extension was commenced at the end of 1 week. With stable fixation splint was discarded after 1 week. Strengthening exercises began at 10 weeks. Active range of motion was regained during the first 2 months. Additional flexion and extension were gained for up to 5 months Works requiring strenuous efforts were avoided for 10 weeks [66].

III. Methods of follow up:

All patients were followed up for at least sixmonths. At the end of the period of follow up, the following data were recorded [56]:

1. Clinically:

- Pain
- Local tenderness and its site
- Signs of infection
- Deformity

a- At the elbow

b- At the site of fracture

- Muscle wasting
- Movements
  - Flexion
  - Extension
  - Pronation
  - Supination
- Measurements
  - Carrying angle

2. Radiologically:

- Degree of union
- Alignment of the distal and proximalfragments
- Degenerative changes of the elbow
- Signs of infection.

IV. Methods of assessment of theresults:

- Maintained joint line

- Good alignment of the fragment
- No signs of infection or non union
- Normal carrying angle

ii) Good:

a) Clinical:

- Activity of daily living
- Slight pain with heavy use
- Arc of flexion 75-110°
- At least 50% of normal supinationand pronation.

b) Radiological:

- Maintained joint line
- Good alignment of the fragments
- Minimal degenerative changes
- No signs of infection or non-union
- Changes of the carrying angle of lessthan 10 degrees.

2. Unsatisfactory results:

i) Fair:

a) Clinical:

- Activities of daily living
- Occasional pain with normal use
- Arc of flexion 60-75°
- Loss of more than 50 % of normalsupination and pronation

b) Radiological:

- Mild loss of joint line
- Fair alignment
- Moderate degenerative changes
- Changes of in the carrying angle ofless than 20 degrees

The results were assessed clinically and radiologically according to the method described by Bickel and Perry as follows [56].

1. Satisfactory results :

i. Excellent;

a) Clinical:

- Heavy work performance
- No pain

- Arc of flexion of at least 110°
- Normal supination and pronation.

b) Radiological:

ii) Poor:

a) Clinically:

The elbow shows any of the followings:

-Used only as a prop

-Constant pain

-greatly restricted motion

b) Radiological:

-Loss of joint line

-Poor alignment

-Marked degenerative changes

- Changes in the carrying angle ofthan 20 degrees

Statistical Analysis

Data were analyzed using SPSS softwarepackage version 18.0 (SPSS, Chicago, IL, USA). Quantitative data was expressed using Range, mean and standard deviation while Qualitative data was expressed in frequency and percent. Qualitative data was analyzed using exact tests such Fisher exact and Monte Carlo to compare different groups. Not normally distributed quantitative data analyzed using Mann Whitney test for comparing two groups. p value was assumed to be significant at 0.05.

a- Mean value $(\bar{X}) = \frac{X}{n}$; Where X = the sum of all observations. n = the number of observations.

b- The standard deviation S.D. $= \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$; WhereS(Xi – X)^2 =the sum of squares of differences of observations from the mean.

c- Fisher's exact test and Monte Carlotest

It is used whenever the expected frequency in any of the cells of 2´2 table falls below 5. This test involves the calculation of the P value directly, without the use of particular test statistic.

$$P = \frac{a+b!c+d!a+c!b+d!}{n!a!b!c!d!}$$

a, b, c, d: are the numbers in each celln: the total sample size.

!: factorial = successive multiplication of theintegers in descending order.

In case of an r x c table the "Monte Carlo".test was used.

It is used for comparing two group medians based on independent samples (by ranking). To test the hypothesis:

- Ho: Mdx = Mdy

d- Mann-Whitney test

- Ha: Mdx > Mdy
- The test statistic U is:

$n_2 (n_2 + 1)$

- U = Uy = Sy - 2
- n2 = number of y values.
- To test:
- Ho: Mdx = Mdy
- Ha: Mdx < Mdy
- The test statistic U is:

$n_1 (n_1 + 1)$

- U = Ux = Sx - 2
- n1 = number of x values. Find thecritical value C for a one-tailed test
- If U £ C, reject Ho

Where S $(Xi – X)^2$ =the sum of squares ofdifferences of observations from the mean.

Results

Overall score

In this study 11 patients had excellent results(55%), 7 patients had good results (35 %), one had afair result (5%), and one patient had a poor result (5%) (Table 11) (Figure 24).

Overall score	No	%
Poor	1	5.0
Fair	1	5.0
Good	7	35.0
Excellent	11	55.0

Table 11: Distribution of the studied casesaccording to overall score

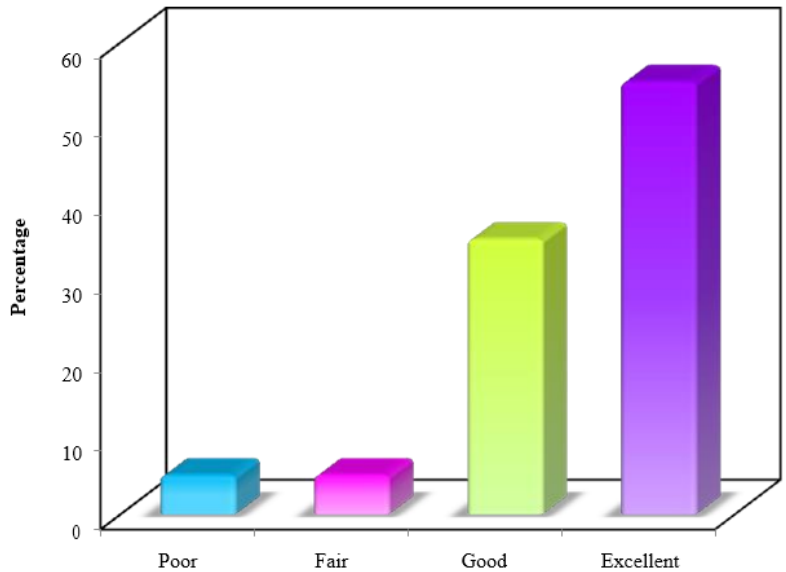

Figure 24: Distribution of the studied casesaccording to overall score

The excellent and good results were considered satisfactory and the fair and poor results considered unsatisfactory so in this study, 18 patients (90%) had satisfactory results, while 2 patients (10%) had unsatisfactory results (Table 12)(Figure 25).

Overall outcome	**No**	**%**
Satisfactory	18	90.0
Unsatisfactory	2	10.0

Table 12: Distribution of the studied casesaccording to overall results.

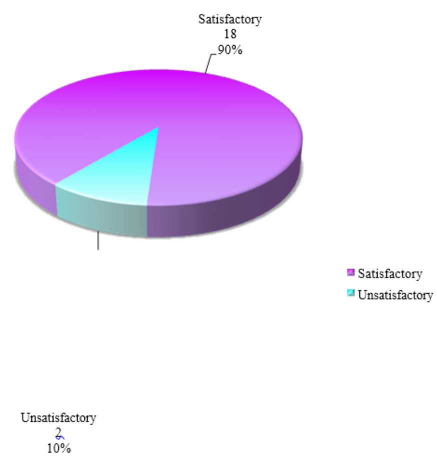

Figure 25: Distribution of the studied cases according to overall results.

(A) Clinical results:

(1) Range of motion

a. Elbow flexion

In 11 patients the range of motion was 110° or more, in 7 patients it ranged between 75°- 109° and in 2 patients it was less than 75° Thus 45% of patients had limitation of elbow flexion motion (Table 13) (Figure 26).

Elbow flexion	No	%
<60	1	5.0
60 – 74	1	5.0
75 – 109	7	35.0
≥110	11	55.0
Min. – Max.	58.0 – 125.0	
Mean ± SD	99.90 ± 21.04	
Median	110.0	

Table 13: Distribution of the studied casesaccording to elbow flexion.

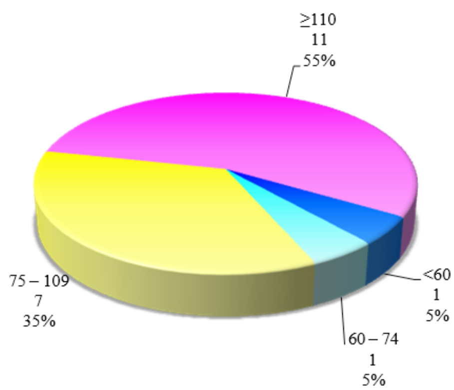

Figure 26: Distribution of the studied casesaccording to elbow flexion.

b. Elbow extension lag

There were 10 patients with elbow extensionlag (50%), 2 of them had 5 degrees (10%), 3 patients had 10 degrees (15%) , 4 patients had 15 degrees and 1 had 30 degrees extension lag (5%).(Table 14) (Figure 27).

Elbow extension lag	No	%
Absent	10	50.0
Present	10	50.0
5	2	10.0
10	3	15.0
15	4	20.0
30	1	5.0

Table 14: Distribution of the studied casesaccording to elbow extension lag.

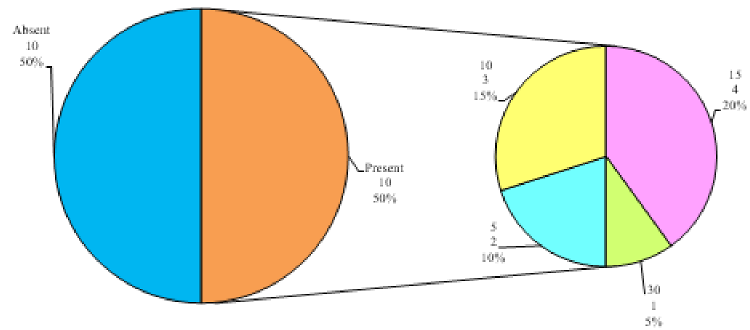

Figure 27: Distribution of the studiedcases according to elbow extension lag.

c. Supination and pronation

Regarding supination and pronation, there were 12 patients with range of motion 70-85° (60%), one patient with range of motion 60-69° (5%), and 5 patients with range of motion50- 59°(25%) and 2 patients 30-49° (10%). (Table 15) (Figure 28).Thus 40% had variable degrees oflimitation of supination and pronation.

Sup/ pronation	No	%
30 – 49°	2	10.0
50 – 59°	5	25.0
60 – 69°	1	5.0
70 – 85°	12	60.0
Min. – Max.	30.0 – 80.0	
Mean ± SD	64.0 ± 14.29	
Median	70.0	

Table 15: Distribution of the studied casesaccording to supination pronation.

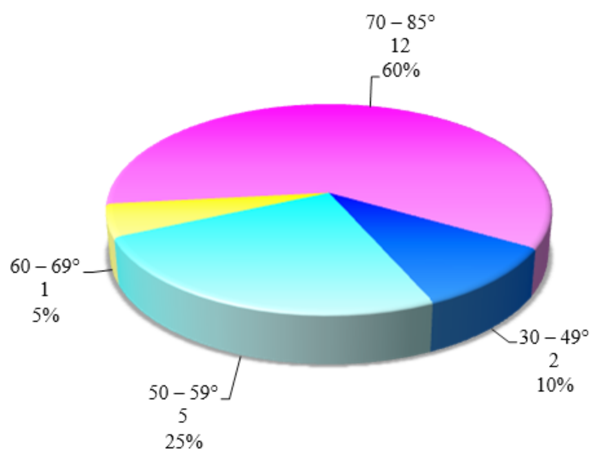

Figure 28: Distribution of the studied casesaccording to supination/pronation.

(2) Carrying angle

There were 10 patients (50 %) with carryingangle ≥11 degrees, 8 (40%) patients with carrying angle 6-10 degrees, one patient (5%) with carryingangle less than 5 degrees and another one (5%) with -5 degrees carrying angle. (Table 16) (Figure 29).

Carrying angle	No	%
-5	1	5.0
0 – 5	1	5.0
6 – 10	8	40.0
≥11	10	50.0
Min. – Max.	-10.0 – 14.0	
Mean ± SD	9.80 ± 5.25	
Median	10.50	

Table 16: Distribution of the studied casesaccording to carrying angle.

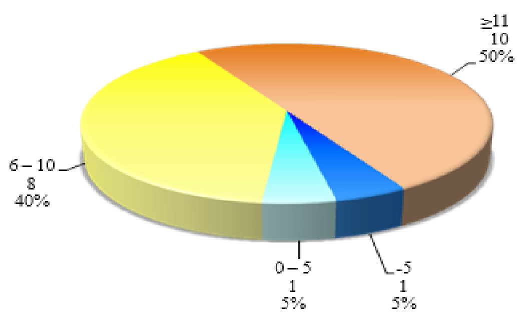

Figure 29: Distribution of the studied cases according to carrying angle.

(3) Pain

Seven patients (35 %) had pain around theelbow: 5 of them had pain on heavy work (25%), one patient has ordinary work (5%) and one patient had pain on rest (5%).(Table 17) (Figure 30).

Pain	No	%
Absent	**13**	**65.0**
resent	**7**	**35.0**
On rest	1	5.0
On ordinary work	1	5.0
On heavy work	5	25.0

Table 17: Distribution of the studied casesaccording to pain.

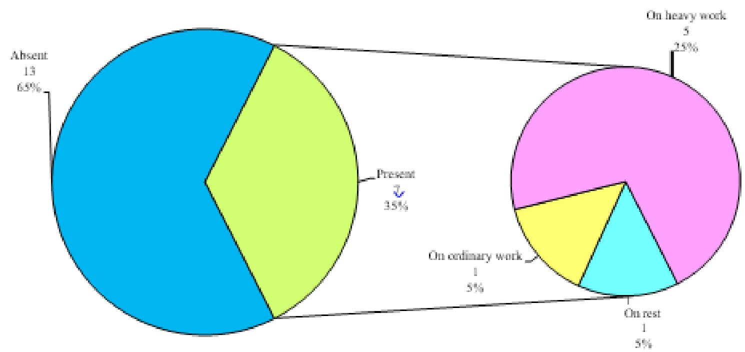

Figure 30: Distribution of the studied casesaccording to pain.

(B) Radiological Results

1- Alignment of the fracture:

There were 2 cases of suboptimal reduction alignment (10%) and 18 cases of perfect reductionalignment (90%). (Table 18) (Figure 31).

Alignment	No	%
Suboptimal	2	10.0
Perfect	18	90.0

Table 18: Distribution of the studied casesaccording to Alignment.

Figure 31: Distribution of the studied cases according to Alignment.

2. Callus formation

In this study, the mean time for callus formation was 11.9 ± 1.62weeks: 3 patietns had callus formation in 10 weeks (15%), 2 patients hadcallus formation in 11 weeks (10%) , 14 patients hadcallus formation in 12 weeks (70%) and one patienthad callus in 18 weeks . (Table 19) (Figure 32).

Callus formation (weeks)	No	%
10	3	15.0
11	2	10.0
12	14	70.0
18	1	5.0
Min. – Max.	10.0 – 18.0	
Mean ± SD	11.90 ± 1.62	
Median	12.0	

Table 19: Distribution of the studied cases according to callus formation (weeks).

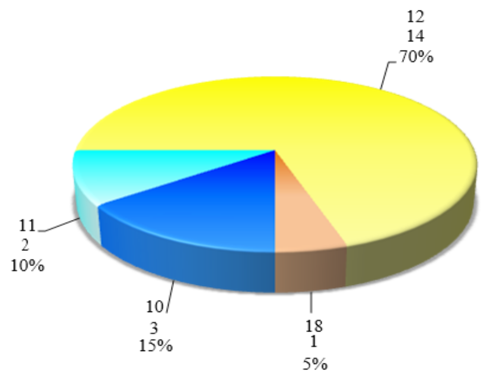

Figure 32: Distribution of the studied cases according to callus formation (weeks).

3. Union

The mean time for full union in this study was 15.45 ± 3.66 weeks. It ranged from 14 to 30 weeks. There were 19 cases (95%) united before 16 weeks and only one case with delayed union till 30 weeks. (Table 20) (Figure 33).

Full union (weeks)	No	%
≤16	19	95.0
>16	1	5.0
Min. – Max.	12.0 – 30.0	
Mean ± SD	15.45 ± 3.66	
Median	15.0	

Table 20: Distribution of the studied casesaccording to full union (weeks).

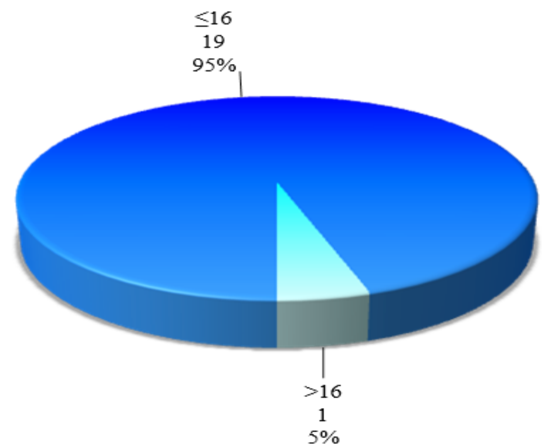

Figure 33: Distribution of the studied casesaccording to full union (weeks).

Complications

Seven cases had complications (35%): one patient had cubitus varus (5%), one patient had deep infection and delayed union (5 %) that recovered after antibiotics and daily dressing, 3 had ulnar neuritis (15%) which disappeared on 4th week postoperatively. and 4 had heterotrophic ossifications (20%). (Table 21) (Figure 34).

Complications	No	%
Absent	13	65.0
Present	7	35.0
Heterotrophic ossification	4	15.0
Ulnar neuritits	3	20.0
Infection, delayed union	1	5.0
Cubitus varus	1	5.0

Table 21: Distribution of the studied casesaccording to complications.

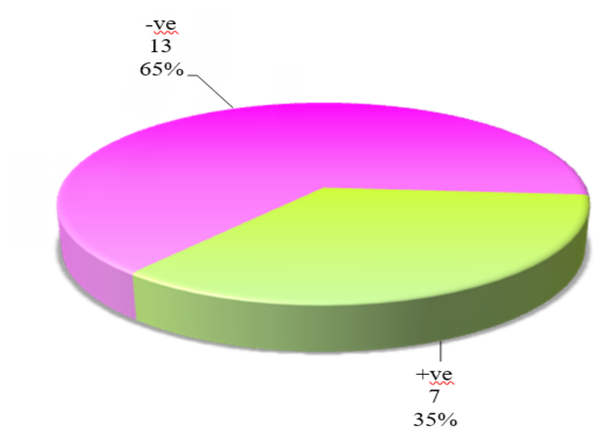

Figure 34: Distribution of the studied cases according to complications.

Relation between head injury and heterotrophic ossification

There was no statistical significance between head injury and heterotrophic ossification in our study (Table 22).

Heterotrophic ossification	Head injuries absent (n = 17)		Head injuries present (n = 3)		FEp
	No	%	No	%	
Absent	15	88.2	1	33.3	0.088
Present	2	11.8	2	66.7	

FEp: p value for Fisher Exact test

Table 22: Relation between head injuries and heterotrophic ossification

Relation between result and heterotrophic ossification

There was statistical significance between final result and heterotrophic ossification. All patients with heterotrophic ossifications had good results (57.1%).and none of patients with excellent results had heterotrophic ossifications (Table 23) (Figure 35).

Table (23): Relation between overall score and heterotrophic ossification

	Overall score: Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent (n = 11)		MCp
	No	%	No	%	No	%	No	%	
Absent	1	100.0	1	100.0	3	42.9	11	100.0	0.025*
Present	0	0.0	0	0.0	4	57.1	0	0.0	

MCp: p value for Monte Carlo test; *: Statistically significant at $p \le 0.05$

Table 23: Relation between overall score and heterotrophic ossification.

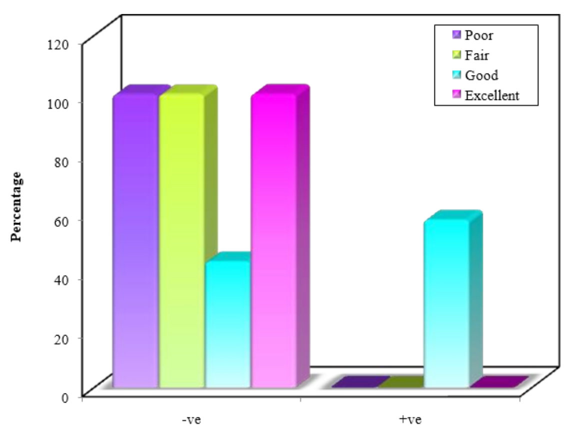

Figure 35: Relation between overall score and heterotrophic ossification.

Factors affecting the results

1. Demographic data (age and sex)

A. Sex of the patients

Sex did not affect the results. Unsatisfactory results occurred in one male patient and one female patient. This was statistically insignificant between sex of patients and results (Table 24) (Figure 36).

Sex	Overall score								MCp
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
Male	0	0.0	1	100.0	5	71.4	6	54.5	0.595
Female	1	100.0	0	0.0	2	28.6	5	45.5	

MCp: p value for Monte Carlo test

Table 24: Relation between overall score and sex.

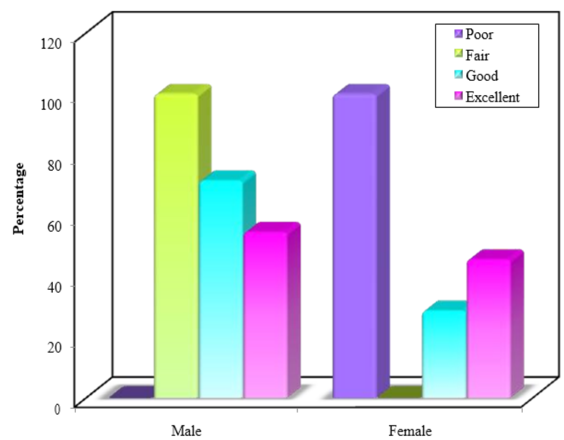

Figure 36: Relation between overall score and sex.

B. Age of the patients

Age did not affect the results. The mean age of patients with excellent results was 35.73 ± 9.87 years, and for patients with good results it was 45.14 ± 17.05 years. The age of patient with a fair result was 45 years and the age of patient with a poor result was 60 years, the difference was statistically insignificance. (Table25)(Figure 37).

Age	**Overall score**								**Test of sig.**
	Poor (n = 1)		**Fair (n = 1)**		**Good (n = 7)**		**Excellent(n = 11)**		
	No	%	No	%	No	%	No	%	
<30	0	0.0	0	0.0	2	28.6	3	27.3	MCp =0.089
30 – 40	0	0.0	0	0.0	0	0.0	5	45.5	
40 – 50	0	0.0	1	100.0	3	42.9	3	27.3	
>50	1	100.0	0	0.0	2	28.6	0	0.0	
Min. – Max.	60.0 – 60.0		45.0 – 45.0		22.0 – 70.0		18.0 – 50.0		p = 0.227
Mean ± SD	60.0 ± -		45.0 ± -		45.14 ± 17.05		35.73 ± 9.87		
Median	60.0		45.0		50.0		35.0		

p: p value for Mann Whitney test MCp: p value for Monte Carlo test

*: Statistically significant at p ≤ 0.05

There was no statistical significance between final results and demographic data.

Table 25: Relation between overall score and age.

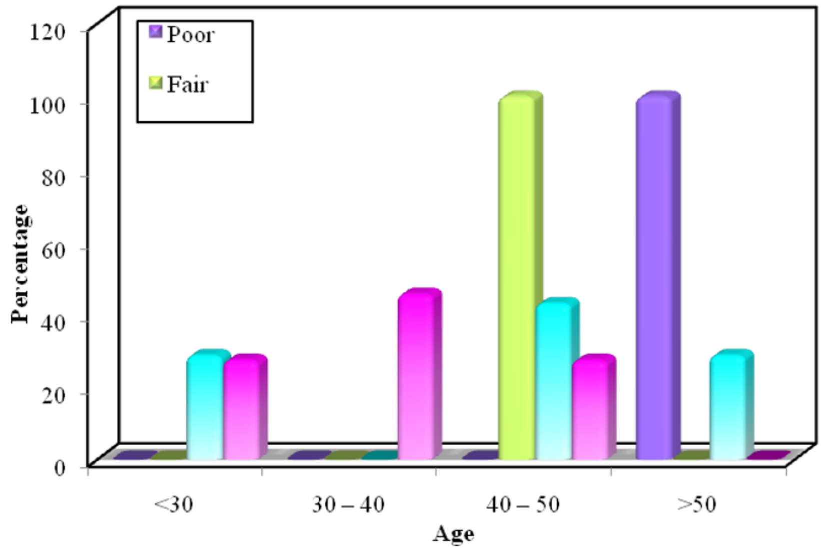

Figure 37: Relation between overall score and age.

2. Fracture type

Statistical significance was found between final results and type of fracture. all unsatisfactory results occurred in type C3 complex fractures. , all patients with C1 fracture type had excellent results, and all patients with C2 fracture had satisfactory results (3 had good results and 5 had excellent results). (Table 26) (Figure 38).

Fracture classification	Overall score								MCp
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
C1	0	0.0	0	0.0	0	0.0	3	27.3	0.508
C2	0	0.0	0	0.0	3	42.9	5	45.5	
C3	1	100.0	1	100.0	4	57.1	3	27.3	

MCp: p value for Monte Carlo test

Table 26: Relation between overall score and fracture classification

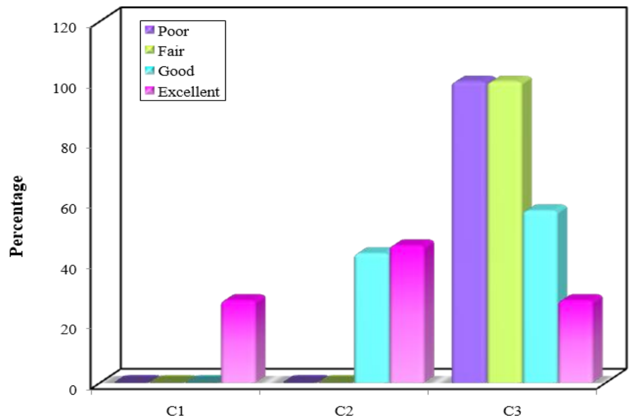

Figure 38: Relation between overall score and fracture classification.

3. Mechanism of injury

There was no statistical significance between final results and mechanism of injury. (Table 27) (Figure 39)

Mechanism of injury	Overall score								MCp
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
RTA	0	0.0	1	100.0	3	42.9	8	72.7	0.436
Simple fall onelbow	1	100.0	0	0.0	3	42.9	3	27.3	
Falling from height	0	0.0	0	0.0	1	14.3	0	0.0	

MCp: p value for Monte Carlo test

Table 27: Relation between overall score and mechanism of injury.

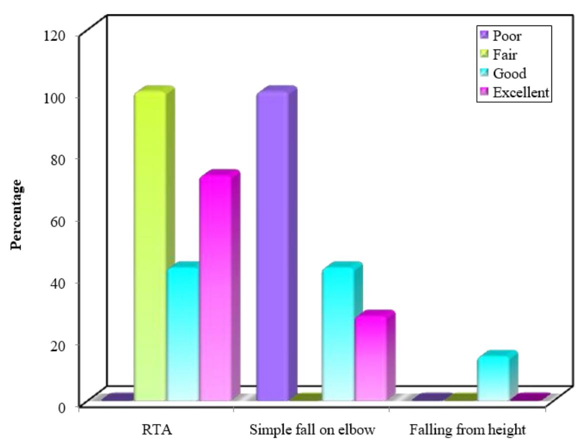

Figure 39: Relation between overall score and mechanism of injury.

4. Open Fractures

There was statistical significance between final results and the presence of open fractures. There were 4 cases with open fractures: one of them had fair result and 3 had good results. No patients with open fractures had excellent results. (Table 28).

Fracturetype	Overall score								MCp
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
Closed	1	100.0	0	0.0	4	57.1	11	100.0	0.027*
Open	0	0.0	1	100.0	3	42.9	0	0.0	

MCp: p value for Monte Carlo test

*: Statistically significant at $p \leq 0.05$

Table 28: Relation between overall score and open and closed

5. Associated injuries

There was statistical significance between final results and associated head injury. We had 4 cases with associated injuries, 1 had fair result and 3 had good results. No patients with associated injuries had excellent results. (Table 29) (Figure 40).

Associated injuries	Overall score								MCp
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
Absent	1	100.0	0	0.0	4	57.1	11	100.0	0.025*
Present	0	0.0	1	100.0	3	42.9	0	0.0	

MCp: p value for Monte Carlo test

*: Statistically significant at $p \leq 0.05$

Table 29: Relation between overall and associated injuries.

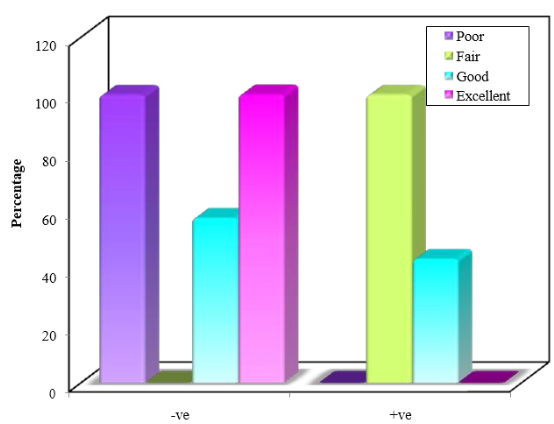

Figure 40: Relation between overall and Associated injuries

6. Time lapse between injury and operation

There was no statistical significance between final results and time lapse before fixation.(Table 30)(Figure 41).

Time lapse (days)	Overall score								Test of sig.
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
1 – 2	0	0.0	0	0.0	1	14.3	11	100.0	MCp <0.001*
3 – 4	0	0.0	0	0.0	6	85.7	0	0.0	
5 – 10	1	100.0	0	0.0	0	0.0	0	0.0	
10 - 14	0	0.0	1	100.0	0	0.0	0	0.0	
Min. – Max.	58.0 – 58.0		70.0 – 70.0		75.0 – 100.0		110.0 – 125.0		p = 0.002*
Mean ± SD	58.0 ± -		70.0 ± -		84.29 ± 10.97		116.36 ± 5.95		
Median	58.0		70.0		80.0		115.0		

MCp: p value for Monte Carlo testp: p value for Mann Whitney test

*: Statistically significant at $p \leq 0.05$

Table 30: Relation between overall and time laps.

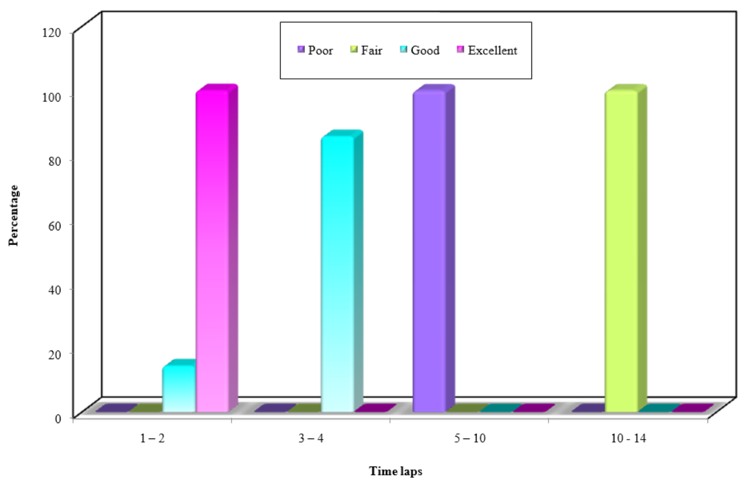

Figure 41: Relation between overall and time laps.

7. Operative Time

There was no statistical significance between operative time and the results. The mean operative time of the patient with a poor result was 70 minutes, and for the patient with a fair result was 60 minutes, the operative time of patients with good results was 50 minutes and was 50 minutes in patients with excellent results (Table 31).

Operative time(minutes)	Overall score								Test of sig.
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
<50	0	0.0	0	0.0	0	0.0	5	45.5	MCp = 0.201
>50	1	100.0	1	100.0	7	100.0	6	54.5	

Min. – Max.	70.0 – 70.0	60.0 – 60.0	50.0 – 55.0	40.0 – 60.0	p = 0.076
Mean ± SD	70.0 ± -	60.0 ± -	50.71 ± 1.89	48.18 ± 6.03	
Median	70.0	60.0	50.0	50.0	

p: p value for Mann Whitney test MCp: p value for Monte Carlo test

*: Statistically significant at p ≤ 0.05

Table 31: Relation between overall score and operative time.

8. Start of elbow motions

There was statistical significance between final results and start of elbow motion. All patients with unsatisfactory results started elbow motion after one week and all patients with satisfactory results started elbow motion within (1-4 days).(Table 32) (Figure 42).

Start of elbowmotions (days)	Overall score								Test of sig.
	Poor		Fair		Good		Excellent		
	No	%	No	%	No	%	No	%	
<5	0	0.0	0	0.0	7	100.0	11	100.0	MCp = 0.006*
5 – 10	1	100.0	0	0.0	0	0.0	0	0.0	
>10	0	0.0	1	100.0	0	0.0	0	0.0	
Min. – Max.	7.0 – 7.0		14.0 – 14.0		1.0 – 5.0		1.0 – 2.0		p = 0.014*
Mean ± SD	7.0 ± -		14.0 ± -		2.29 ± 1.25		1.27 ± 0.47		
Median	7.0		14.0		2.0		1.0		

MCp: p value for Monte Carlo testp: p value for Mann Whitney test

*: Statistically significant at p ≤ 0.05

Table 32: Relation between overall and start of elbow motions.

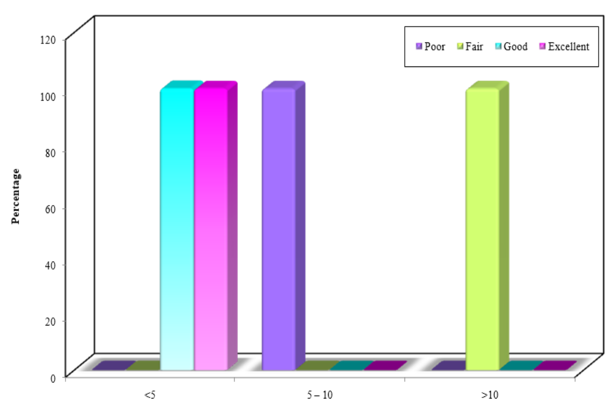

Figure 42: Relation between overall and start of elbow motions.

9. Associated morbidities

There was statistical significance between final results and associated morbidity. The patient with poor result was diabetic and hypertensive, none of patient with excellent results had any associated morbidity (Table 33).

Associated morbidities	Overall score								MCp
	Poor (n = 1)		Fair (n = 1)		Good (n = 7)		Excellent(n = 11)		
	No	%	No	%	No	%	No	%	
Absent	0	0.0	1	100.0	5	71.4	11	100.0	0.049*
Present	1	100.0	0	0.0	2	28.6	0	0.0	

MCp: p value for Monte Carlo test

*: Statistically significant at $p \leq 0.05$

Table 33: Relation between overall score and associated morbidities

Case Presentation

Case number 1

A male patient 29 years old, was involved in a road traffic accident which caused intercondylar fracture of distal right humerus type C3, The patient was a heavy manual worker, with no associated morbidities, or injuries, patient was operated one day after admission and operation time was about one hour. He began active elbow motion two days after operation. The fracture united after 14 weeks with no complications. The patient result was excellent. (Figure 43,44).

Figure 43: X-ray showing intercondylar fracture of humerus type C3.(a) anterior view (b) lateral view.

Figure 44: X-ray 6 months post operatively showing complete union.(a) anterior view (b) lateral view.

Case number 2

A female patient 55 years old, was involved in a simple fall which caused intercondylar fracture of distal right humerus type C3, patient was adopting sedentary work, diabetic on insulin therapy, no associated injuries, patient operated upon 4 days after admission and operation time was about one hour. She began active elbow motion 2 days after operation. The fracture united after 16 weeks with pain on heavy work, elbow flexion was about 75°, elbow extension lag of 10°,supination about 60° and the carrying angle was 11°. The patient result was good (Figure 45-47).

Figure 45: X-ray showing intercondylar fracture of humerus type C3.(a) anterior view (b) lateral view.

Figure 46: Immediate post operative X-rays .(a) anterior view (b) lateral view.

Figure 47: X-rays 6 months after operation showing complete union.

Case number 3

A male patient 45 years old, was involved ina road traffic accident which caused intercondylar fracture of distal right humerus type C3, The patient was a heavy manual worker, with head injury and patellar and ribs fractures admitted to intensive care unit, The patient operated upon 14 days after admission and operation time about onehour. He began active elbow motion 8 days after operation. The fracture had delay union 7 months later, the patient had ulnar neuritis and deep infection that had resolved on daily dressing and parentral antibiotics. He had pain on rest, elbow flexion was about 70°, elbow extension lag of 15°,supination about 40° and the carrying angle was 3°and tenderness at fracture site. The patient resultwas poor. (Figure 48,49)

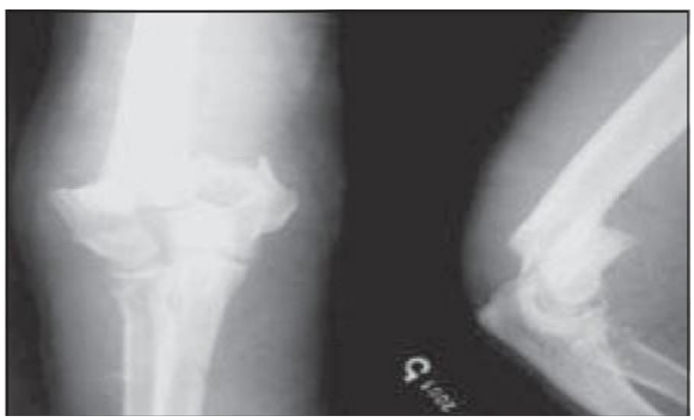

Figure 48: X-ray show intercondylar fracture ofhumerus type C3.(a) anterior view (b) lateral view.

Figure 49: X-ray 6 months post operativelyshowing delayed union.(a) anterior (b) lateral view.

Discussion

Intercondylar fractures of the humerus are some of most difficult and controversial fractures to treat. Perior to the last two decades the consensus favoured non-operative management because of the poor operative results. In the last quarter century improved outcomes have been reported with surgery for distal humerus fractures.The last decade has seen advances in the understanding of elbow anatomy, improvement in surgical approaches, new innovative fixation devices and evaluation of postoperative rehabilitation protocols [1]. In the present study, the mean age was 41 years old which was nearly similar to that reported in Gupta et al [71] (39 years). However it was less than that in Atalar et al [67] (47 years), an Tyllianakis et al [68] (46.1 years). But more than that reported in kilicarslan et al [69] (24.8years), and Ali et al [70](32.5 years). Males (60%) were affected more than females (40%). The predominance of males was also found by many authors as Atalar et al. [67](66.6% males) and Gupta et al. [71] (66.6% males), Ali et al [70] (72.7% males) and Kilicarslan et al. [69] (77% % males) and this can be explained by more active mode of life in males in comparison to females. On the contrary Tyllianakis et al [68] found more prevalence of females in their series (53%). Road traffic accidents were the most common mechanism of injury (60%) in our study. This was similar to Atalar et al. [67] study (57.1% of patients were victims of road traffic accidents) and dissimilar to the series of Gupta et al [71], Tyllianakis et al [68], and Ali et al [70] as they reported that simple fall on elbow was the most common mechanism of injury. This can beexplained by the high incidence of road traffic accidents in Egypt.

Regarding AO classification, all patients hadtype C- complex fractures, and this was similar tomost of studies. [69-73] Type C 3 fractures were the most common type of fractures in our study (45%)and this was similar to the finding of Atalar et al [67] (51.1%), kilicarslan et al [69] (44.4%), and Tyllianakis et al [68] (38.5%). While type C 2 fractures were more common in Gupta et al [72] (41.8%) and Ali et al [70] (50%). Twenty percent of fractures in our study were open. In Gupta et al [71],10.9% of fractures were open. In Ali et al [70] study 13.6% of fractures were open. Higher incidence of open fractures was reported by Atalar et al [67] (38%), kilicarslan et al [69] (40.7%) and. Tyllianakis et al [68](30.8%). Regarding associated injuries, 20% of patients had associated injuries most commonly head injuries .In Atalar et al [67] study 47.4% of patients had associated injuries mainly fracture pelvis and head injuries This explains the long time laps between admission and operation, and the high incidence of heterotrophic ossification in that study. In Gupta et al [71] study 30% of the cases had associated injuries elsewhere in the body, 5 of them (12 cases) had ipsilatral upper limb trauma. In Tyllianakis et al [68] Study (29%) of patients had associated injuries, 5 of them(10 cases) had ipsilateral upper limb trauma and 1 had ipsilatral brachial artery injury . In Ali et al [70] study 20% of patients had associated injuries. The more associated injuries, the more time lapse between admission and operation time and less final outcome. The mean time lapse between injury and fixation in our study was 2 days. This was the same as reported by kilicarslan et al [69] and Tyllianakis et al [68].

Shorter time lapse before fixation was reported in Ali et al [70] study (12hours). Longer time lapse was reported in the series of Atalar et al [67] (6 days) and Gupta et al [71] (7 days). The longer time lapse in these studies was due to the higher incidence of associated injuries in their patients(47.6%, 30.9% respectively). Bryan-Morrey approach was used for all patients in our study , while olecranon osteotomy was used by Atalar et al [67], kilicarslan et al [69] and Tyllianakis et al [68]. Gupta et al [71] used V shaped tricepse appourosis reflection technique , while Ali et al [70] used extensor mechanism sparing paratriceptal post approach. Regarding plating technique, double reconstruction plates (90-90 orthogonal plating)were used in all cases of the present study , Gupta et al [71] and Ali et al [70] used the same technique, while Atalar et al [67] and kilicarslan et al [69] and used double parallel technique by Mayo anatomic plates, Tyllianakis et al [68] used in 11 patients DCPor third tubular double plate orthogonal or paralleland used DCP or third tubular plate in one side and free screws or kirchner wires or both in the other side in the remaining 15 patients. In all studies, elbow motion started within 48 hours from operation time. Regarding final score, we had 55% excellentresults, 35% good results, 5% fair results and 5% poor results. This was nearly similar to the results of A.M.Ali et al [70] which were excellent in 59.2%, good in 27.3% ,fair in 9% and poor in 4.5%. Higher incidence of excellent results were achieved by kilicarslan et al [69] (76%) results and Gupta et al [71] (74.4%).

Lower incidence of excellent results were achieved by Tyllianakis et al [68] (23%) and Atalar et al [67] study (33%). The Low incidence of excellent results in these studies can be explained by the increased mean age of their patients (46.1,47 years) respectively , The high percentage of complex type C fractures. The high incidence of associated injuries. The Long time lapsed between admission and operation and the higher incidence of heterotropic ossification. On the other hand, the low mean age (24.8 years),the low incidence of associated injuries (14%), and the low incidence of heterotrpic ossifications (7%) can explain high incidence of excellent results in kilicarslan et al [69] study. Satisfactory results in this study occurred in 90% of the patients this is nearly similar to the results of Gupta et al [71](92%),Ali et al [70] (86.6%),Atalar et al [67] (86%) and M. Tyllianakis et al [68] (83%). The unsatisfactory results occurred in 2 patients (10%) who had limited range of elbow motion, abnormal carrying angle, unstable elbow. Pain during rest and more on ordinary work in the other, and one of them had cubitus varus. Both patients had fracture type C3 and associated injuries elsewhere also.

Complications

Herterotopic ossification in our study occurred in 4 patients(20%): one of them had a fair result and 3 had good results. Higher incidence of heterotopic ossification occurred in Atalar et al [67] study 33% because there was higherincidence of head injuries and higher mean age (47 years). Lower incidence of heterotopic ossification was reported in the series of Gupta et al. [73] (5%), kilicarslan et al [61] (7%)and Tyllianakis et al [60] (11 %) Had heterotropic ossification. No patients with heterotropic ossification occurred in Ali et al [62] study. The relatively high incidence of heterotropicossification in our series is attributed to the presence of head injury in 15% of the cases and the relative high mean age(41 years). Infection occurred in this study in one patient (5%) and improved on daily dressing and systemic antibiotics. This is similar to the findings of Atalar et al [69] (4%), Gupta et al [73] (3.6%), kilicarslan et al [71] (3.7%) and Ali et al [72] (4.5%).Higher incidence of infection occurred in M. Tyllianakis et al [70] Study 2 patients (7.6%) as it had high median age 46.1 and high incidence of open fractures 8 patients 30.8%. Decreased incidence of infection in most of the studies is due to early operation, use of prophylactic antibiotics and reduced operation time and operative techniques that progress in last decade. Ulnar neuritis occurred in 3 patients (15 %) that disappeared on the 4^{th} week post operatively. Ulnar neuritis occurred in Gupta et al [73] study in 5% and in Tyllianakis et al [70] Study in 11 % and disappeared on the 4^{th} week postoperatively in the both studies. No cases of ulnar neuritis were reported in the studies of Atalar et al [69], kilicarslan et al [71] and in Ali et al [72]. One patient (5%) had cubitus varus deformity. She was osteoprotic female with highlycomminuted type C3 fracture. No implant related complications were reported in this study and none of patients needed revision of surgery. In Gupta et al [72] study, one patient had implant failture (1.8%) that needed revision with new device. In kilicarslan et al study, [71] 8 patients (29%) had joint deformity (cubitus varus and cubitus valgus). In Tyllianakis et al [70] study, one patient(3%) had ulnar nerve palsy due to prolonged traction of ulnar nerve that recovered spontaneously after 9 months, 4 patients (15%) had wires migrations and 2 patients (7.5%) had implant failure This study had higher incidence of reoperation (38%). In Ali et al [72] study, one patient (4.5%) had subcutaneous prominence of hard ware that needed reoperation. No other complications reported in Atalar et al [69] study

Summary

The aim of this work was to study the resultsof internal fixation of intercondylar fractures of distal humerus in the adults by double plate technique.Twenty patients with intercondylar fracturesof distal humerus were treated by internal fixation by double plate technique from January 2011 to July 2012 in El-Hadara University Hospital.

Males (60%) were affected more than females (40%). The age of patients ranged from 18 to 71 years with an average of 41 years. Road traffic accidents were the commonest cause of injury (60%).The right side was affected in 65% of patients, while the left side was affected in 35%of patients. The most common associated injuries were head injuries (15%), one of them had ribs fractures and fracture patella that needed admission to intensive care unit.Fixation of the fractures was done after stabilization of the patient's general condition with a mean time lapse between injury and fixation 1-2 days. The mean operative time was 50 minutes (ranged from40-70 minutes). Elbow motion was allowed 1-2 days postoperatively and full union was obtained from 14-30 weeks. The results of treatment were assessed by a modification of the method adopted by Bickel andPerry.[56] Eleven patients had excellent results (55%) , 7 had

good results (35%) , one had a fair result (5%) and one had a poor result (5%) so 18 patients had satisfactory results. 2 patients had unsatisfactory results. Complications occurred in 7 patients: heterotopic ossification in 4 patients, deep infection and delayed union in 1 patient ,ulnar neuritis in 3 patients and 1 patient with cubitus varus.

Conclusions

- Internal fixation by double plate technique give satisfactory results in management ofintercondylar fractures of distal humerus.
- Rigid fixation and early elbow mobilization have great influence on the end results.
- Fracture Type C3 and open fractures have adverse effect on the end results.
- Limitation of motion of the elbow and forearm is not uncommon after internal fixation of the intercondylar fracture of the distal humerus.

Comlpications after intercondylar fracture of distal humerus include elbow stiffness, heterotopic ossification, non-union,neuropathy, deep infection and osteoarthrosis

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