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Review Article

A REVIEW OF THE FIXATION STRATEGIES FOR THE FRACTURES OF LATERAL END OF CLAVICLE

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Abstract

Clavicle fracture is a common injury accounting for 2.6-5% of all injuries. The Lateral end of clavicle is an uncommon site of fracture. Conservative management of these fractures with numerous complications. There are many operative techniques available for fixation of these fractures. Operative management has been associated with reduced complication rates but no one particular method has been shown to be superior over others in terms of functional outcome and fracture union. Here we review the 3 commonly used techniques with regards to functional and radiological outcomes.

Keywords: Lateral end Clavicle fractures, Internal fixation, Functional outcomes.

INTRODUCTION

Fractures of the clavicle are common injuries of adults, accounting for about 2.6 to 4% of all injuries (1). They are often caused by either a direct blow to the anterior chest wall or by a fall on the outstretched hand. Clavicular fracture has bimodal age distribution. First peak occurs in young active adult males less than thirty years of age. Usually they have a direct force applied to the shoulder as a result of a fall over the shoulder and less commonly by a fall over an outstretched hand. Second peak occurs in elderly females with osteoporotic bones. The commonest site of fracture in clavicle is the mid-shaft followed by the lateral end fracture which constitutes 21-28% of all clavicle fractures (2). Of these lateral end clavicle fractures 10-52% are displaced fractures which are unstable due to the displacing forces acting on the fracture fragments: an inferior force on the lateral clavicle fracture fragment and an antero-superior force on the medial clavicle fragment (1). The association with acromion through acromioclavicular joint and relationship with coracoid providing vertical stability via coracoclavicular ligament makes its management challenging and controversial. The lateral fractured fragment is small and hence, it is difficult to get an anatomical reduction and also poses problems in its fixation, which results in instability of the lateral clavicle fractures. Various fixation strategies are available for the management of these fractures. Non operative management of these fractures results in high rate of nonunion (1) The causes of this high rate of non-union are mechanical and anatomical. The trapezius and sternocleidomastoid pull the medial fragment superiorly and posteriorly and the weight of the arm displaces the lateral fragment distally . The small size of the distal fragment and the planar shape of the clavicle make bone contact difficult and impede consolidation. So there is a need for surgical stabilization of these fractures using various techniques.

A review of the Anatomy

Embryology: The embryology of the clavicle is unique in that it is the first bone in the body to ossify (fifth week of fetal life), and is the only long bone to ossify by intramembranous ossification without going through a cartilaginous stage(3)(4). The ossification center begins in the central portion of the clavicle; this area is responsible for growth of the clavicle until up to about 5 years of age. Epiphyseal growth plates develop at both the medial and lateral ends of the clavicle, but only the sternal ossification center is present radiographically. This medial growth plate of the clavicle is responsible for the majority of its longitudinal growth, and probably contributes as much as 80% of the length of the clavicle. The sternal ossification center appears and fuses relatively late in life, with ossification occurring between the ages of 12 and 19 years and fusion to the clavicle occurring at 22 to 25 years of age(5).

Bony anatomy of clavicle: The clavicle is a relatively thin bone, widest at its medial and lateral expansions where it articulates with the sternum and acromion, respectively. Although it appears almost straight when viewed from the front, when viewed from above, the clavicle appears as an S-shaped double curve that is concave ventrally on its outer half and convex ventrally on its medial half. The clavicle is the sole bone strut connecting the trunk to the shoulder girdle and arm, and it is the only bone of the shoulder girdle that forms a synovial joint with the trunk.(6) Its name is derived from the Latin word *clavis* (key), the diminutive of which is *clavicula,* a reference to the musical symbol of similar shape. The cross section of the clavicle differs in shape along its length; it varies from flat along its outer third to prismatic along its inner third. The exact curvature of the clavicle and its thickness, to a high degree, vary according to the attachments of muscles and ligaments (6) The flat outer third is most compatible with pull from muscles and ligaments, whereas the tubular medial third is a shape consistent with axial pressure or pull. The junction between the two cross sections varies with regard to its precise location in the middle third of the clavicle. This junction is a weak spot, particularly with axial loading, which may be one of several reasons why fractures occur so commonly at the middle third.

Ligamentous anatomy of lateral end of clavicle

The lateral end of the clavicle articulates with the anterior aspect of the acromion, the anterior extension of the spina

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scapulae. Like the SC joint, the AC joint is a diarthrodial joint with four planes of motion: anterior/posterior and superior/inferior.

Fig. 1. Anterior view. The clavicle (C) is fairly straight. The lateral end is thin, whereas the medial end is robust and bulbous

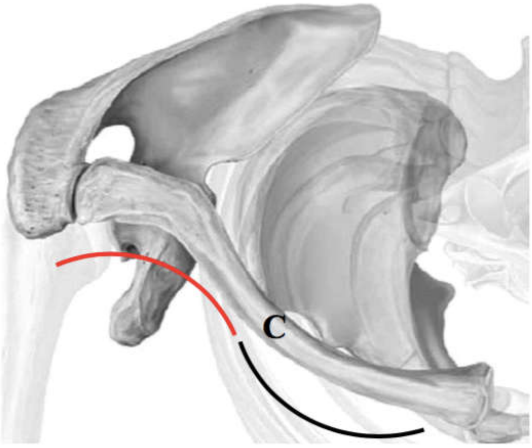

Fig 2. The clavicle (C) has a double curvature: in the medial half is a convex anterior curve (black line) and in the lateral half is a concave anterior curve (red line).

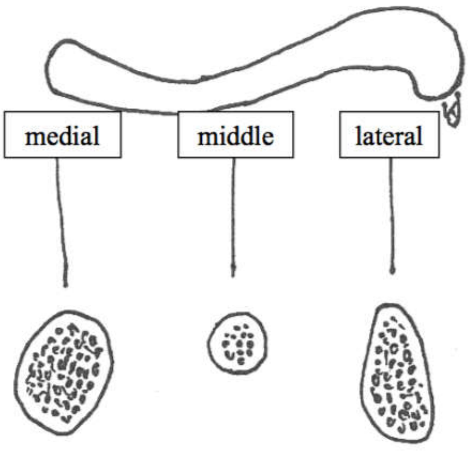

Fig. 3. Cranial view of left clavicle and cross-sections from the medial, middle, and lateral part. Bone porosity increases towards both ends

The AC joint is stabilized by the joint capsule, the AC ligaments, the muscle attachments, and the coracoclavicular (CC) ligaments) (7) Of the four AC ligaments (superior, inferior, anterior, and posterior), the superior and posterior ligaments are the most important in restraining the posterior translation of the lateral clavicle (7, 8). The study of Fukuda *et al.* (7) confirmed the importance of the AC ligament in lateral clavicular stability. They found it to be the primary constraint against posterior and superior displacement of the clavicle. The AC ligament is very short, starting in the clavicle 0.7 to 1.4 mm from the articular surface and in the acromion 1.1 to 2.0 mm from that surface.(9). The AC joint has a disk that undergoes rapid disintegration beginning in the second decade and is rarely evident after the fifth decade (10) The CC ligaments consist of a posteromedial conoidal part and an anterolateral trapezoidal part. This ligament complex attaches the lateral clavicle to the coracoid process of the scapula and restrains the superior and posterior translation (7). The trapezoid ligament originates from the lateral side of the coracoid process and attaches to the undersurface of the clavicle approximately 5 to 13 mm from the lateral edge of the clavicle. The conoid ligament originates from the posteromedial margin of the coracoid process and attaches to the conoid tubercle at the posterior margin of the clavicle approximately 15 to 36 mm from the lateral edge of the clavicle. The length of the trapezoid ligament is 14 to 16 mm, and of the conoid ligament, 10 to 11 mm. The trapezoid ligament has a footprint area in the clavicle and in the coracoid process that is 3 to 4 times as large as that of the conoid ligament (11).

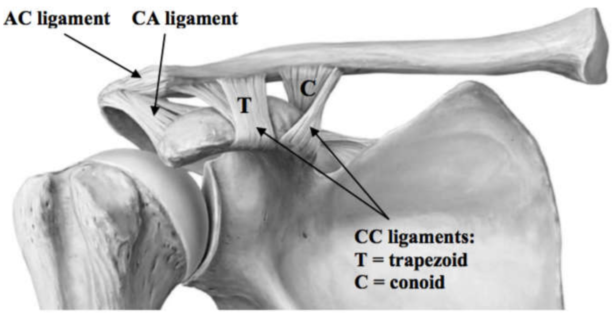

Fig 4. Ligaments stabilizing the lateral end of the clavicle. Anterior view of right clavicle

Muscular Anatomy of Clavicle

The clavicle serves as the attachment site of several large muscles. Medially, the pectoralis major muscle originates from the clavicular shaft antero-inferiorly, and the sternocleidomastoid originates superiorly. The pectoralis origin merges with the origin of the anterior deltoid laterally, while the trapezius insertion blends superiorly with the deltoid origin at the lateral margin. Muscle attachment plays a significant role in the deformity which results after fracture. The medial clavicular fragment is elevated by the unopposed pull of the sternocleidomastoid muscle, while the distal fragment is held inferiorly by the deltoid and medially by the pectoralis major. The undersurface of the clavicle is the insertion site of the subclavius muscle, which is of little significance functionally but serves as a soft tissue buffer in the subclavicular space superior to the brachial plexus and subclavian vessels. The platysma or "shaving muscle" is variable in terms of thickness and extent, but usually envelopes the anterior and superior aspects of the clavicle and runs in the subcutaneous tissues, extending superiorly to the mandible and the deeper facial muscles. It is divided during the surgical approach, and is typically included in the closure of the superficial, or skin/subcutaneous layer.

Neurovascular Anatomy of clavicle

The brachial plexus, at the level at which it crosses beneath the clavicle, consists of three main branches. Of these branches, two are anterior.

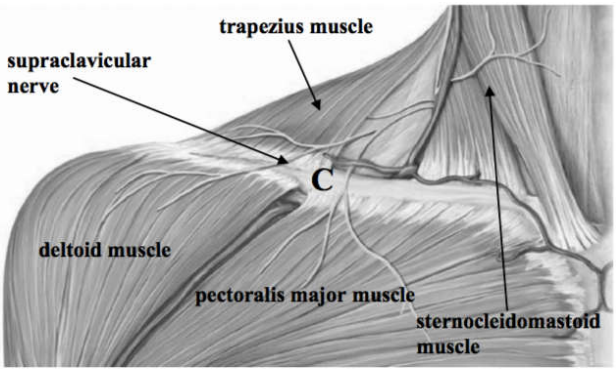

Fig 5. Muscular Anatomy of clavicle

One (lateral) branch originates from the fifth, sixth, and seventh cervical roots and forms the musculocutaneous nerve and a branch of the median nerve; the other (medial) originates from the eighth cervical and first thoracic roots, and forms another branch of the median nerve, the entire ulnar nerve, and the medial cutaneous nerve. The posterior branch of the plexus forms the axillary and radial nerves. The cord of the brachial plexus, which contains the first components of the ulnar nerve, crosses the first rib directly under the medial third of the clavicle. The other two cords are farther to the lateral side and posterior. Therefore, the ulnar nerve is more often involved in complications arising from fractures of the medial third of the clavicle. The space between the clavicle and the first rib has been called the *costoclavicular space.* This space has been measured in gross anatomic studies and often appears to be quite adequate. However, it is not as large in a living subject as in a cadaver, possibly because in a living subject, the vessels are distended and the dimensions of the cords of the brachial plexus are larger than in a cadaver. In addition, in a living subject, the space is diminished as the first rib elevates because of contraction of the scalenus anticus. Hence when the inner end of the outer fragment of the fractured clavicle is depressed, there is much less space between the first rib and the clavicle; the result is that the vessels (especially the subclavian and axillary vessels) and nerves (especially the ulnar nerve) are potentially subject to injury, pressure, or irritation. The internal jugular, which is adjacent to the sternoclavicular joint, is not usually injured with middle-third fractures, but has the potential for injury in more medial trauma involving the sternum and sternoclavicular joint. The subclavian vessels, because of their relative proximity to the medial third of the clavicle, can also be injured during operative treatment of clavicle fractures (12) The clavicle also appears to be unique as a long bone in that it has only a periosteal blood supply and little, if any, intramedullary (IM) or nutrient arterial blood supply. More importantly, the periosteal blood supply has been found to be primarily on the anterior and superior surface of the clavicle. This blood supply, coupled with the poor soft tissue coverage of the clavicle, may be an important consideration in fixation of the clavicle, particularly when significant soft tissue stripping is necessary.

Fracture Classifications

To be effective, a classification system should be accurate in terms of identifying the pathologic anatomy, and it should be able to predict outcome, thereby serving as a basis for deciding on proper treatment. Ideally, a classification system should also be sufficiently straightforward that it is easily reproducible with good intraobserver and inter- observer reliability. Unfortunately, most clavicle fracture classification systems are merely descriptive and give no guidance in terms of prognosis. Although clavicle fractures have been classified by fracture configuration (e.g., greenstick, oblique, transverse, comminuted), the usual classification is by the location of the fracture because location appears to better compartmentalize our understanding of fracture anatomy, mechanism of injury, clinical findings, and alternative methods of treatment. One of the early classifications of clavicle fractures was Allman's classification. This classification was divided into three groups:

Group I: Fractures of the middle third
Group II: Fractures of the distal third
Group III: Fractures of the medial third

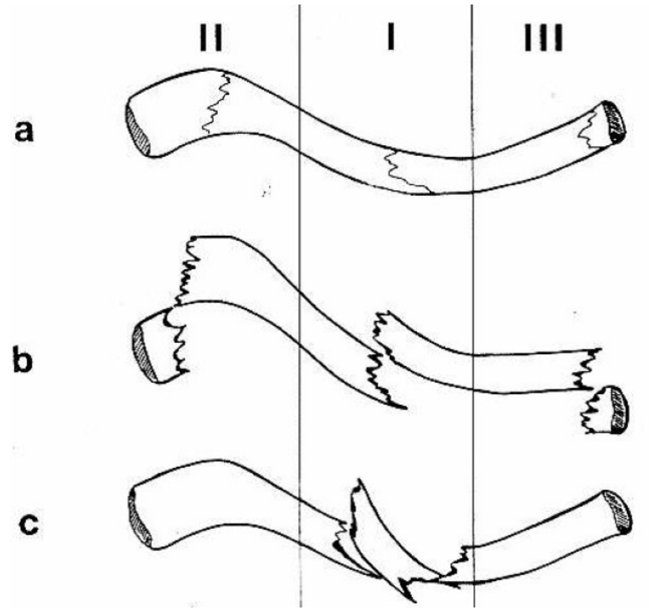

Fig 6. Allman Classification

In 1968, Neer classified lateral end of clavicle fractures according to their location about the coracoclavicular ligaments. Later, Rockwood et al modified the classification. This classification is widely accepted and has got the prognostic value as in type II fractures, unbalanced downward force such as the weight of the arm and vertical muscle forces acting on the medial clavicle end keep the fractured end distracted and hinder union. In type IIb fracture, the loss of conoid ligament restraint on the lateral fragment could result in instability and showed a high incidence of delayed union and nonunion rate. Hence, the surgical treatment may be necessary for type II fractures for the union of the fracture.

TYPE	DESCRIPTION
I	Coracoclavicular ligaments intact, attached to medial segment
II	Coracoclavicular ligaments detached from medial segment, but trapezoid intact to distal segment
IIa	Both conoid and trapezoid attached to distal segment
IIb	Conoid is torn
III	Intraarticular extension into acromioclavicular joint

Fig 7. Neer Classification

Group I: Fracture of the middle third
Group II: Fracture of the distal third
- Type I: Minimal displacement (interligamentous)
- Type II: Displaced secondary to a fracture medial to the coracoclavicular ligaments
  - A. Conoid and trapezoid attached
  - B. Conoid torn, trapezoid attached
- Type III: Fractures of the articular surface
- Type IV: Ligaments intact to the periosteum (children), with displacement of the proximal fragment
- Type V: Comminuted, with ligaments attached neither proximally nor distally, but to an inferior, comminuted fragment

Group III: Fracture of the proximal third
- Type I: Minimal displacement
- Type II: Displaced (ligaments ruptured)
- Type III: Intra-articular
- Type IV: Epiphyseal separation (children and young adults)
- Type V: Comminuted

Fig 8. Craigs Classification

FUNCTIONS AND KINEMATICS OF CLAVICLE

The human clavicle is the only bony connection between the upper limb and the axial skeleton. The clavicle is functionally connected to the internal and external jugular veins as well as to the subclavian vein through the muscles and fascia of the neck and pectoral regions. Contraction of these muscles and movement of the clavicle work together as a circulation and ventilation pump for the arm, head, and neck. The clavicle stabilizes the shoulder girdle with its ligaments and muscle attachments and acts as a strut allowing more degrees of freedom in the shoulder joint. Due to the clavicle, the great nerves and vessels situated beneath have a bony shelter. Another consideration is that the elevation of the upper limb and the motion of the clavicle assist high costal inspiration. Harmonious and continuous motion in the shoulder joint requires simultaneous action in three bones: the humerus, scapula, and clavicle, and in four joints: the glenohumeral, acromioclavicular, sternoclavicular, and scapulothoracic. Any interruption in this delicate scapulohumeral rhythm may cause dysfunction in the human being's most mobile joint. Kinematics of the clavicle is closely connected to the scapulohumeral rhythm. Flexion and abduction of the upper limb at the GH joint is accompanied by scapulothoracic and clavicular movements. In the first 30 degrees of abduction and 60 degrees of flexion, the stability of the scapula is highly irregular. This early phase of motion is related to the setting action of muscles. Between 30 and 170 degrees of abduction and flexion, for every 15 degrees of motion, 10 degrees occurs at the GH joint, and 5 degrees by rotation of the scapula on the thorax. In the upper limb's flexion and abduction, the total range of scapular motion is 60 degrees and of GH motion 120 degrees (13) found in cadaveric shoulders that the majority of the scapular and clavicular rotation occurs after 90 degrees of humeral elevation. During limb elevation, the scapula retracts, rotates laterally, and tilts backward. During elevation of the upper limb, the continuous rotation of the scapula on the thoracic wall is possible only due to the motion permitted at the two clavicular joints. The clavicle rises in the SC joint during the upper limb elevation. This movement begins early and is almost complete during the first 90 degrees, when for every 10 degrees of limb elevation, the clavicle rises 4 degrees. Above 90 degrees, clavicular elevation in the SC joint is almost negligible. In the AC joint, the angle change between clavicle and spina scapulae totals 30 degrees during limb elevation. The clavicle motion occurs early in the first 30 degrees, and late, after 135 degrees of limb elevation. The clavicle also rotates around its long axis during upper limb elevation. The total backward rotation of the clavicle is 50 degrees during limb elevation. During the first 90 degrees of elevation, only 10 degrees of clavicle rotation occur, whereas the other 40 degrees of rotation occur after 90 degrees of elevation. Motion in the SC joint during elevation is characterized by increasing clavicular retraction, elevation, and backward rotation relative to the thorax. In the AC joint, only minor (15-20 degrees) backward rotation occurs. In protrusion and retraction of the shoulders, movement of the clavicle takes place at the SC joint, and no substantial motion happens at the AC joint, nor does the clavicle rotate. During upper limb elevation, the CC ligaments lengthen approximately 3 mm. The last 30 degrees of scapular rotation are possible only by clavicle rotation and CC ligament lengthening.

Surgical Treatment of Lateral end Clavicle Fractures

- Osteosynthesis with locking Plates

In 1958, the AO formulated four basic principles, which have become the guidelines for internal fixation. Those principles as applied to the LCP Superior Clavicle Plate are:

- Anatomic reduction

Precontoured plate assists in anatomic reduction.

- Stable fixation

Locking screws create a fixed-angle construct providing angular stability.

- Preservation of blood supply

Tapered end for subcutaneous plate insertion preserves tissue viability. A limitedcontact plate design reduces plate-to-bone contact and helps to preserve the periosteal blood supply.

- Early, active mobilization

Early mobilization per standard AO technique creates an environment for bone healing, expediting a return to optimal function.

In 2003, Anderson et al (14) reported 13 cases of lateral clavicular fractures fixed with the locking LCP plate and concluded that superior locking plates provided high union rates along with good functions and low complications rates. In 2010, Klein et al. (15) described the use of precontoured plates designed specifically for the distal clavicle. The study group had a high union rate (near 100% overall) and relatively few complications. Of 64 total patients, there were five reported complications, including two infections, two occurrences of screw loosening, and one malunion. In 2011, Anderson J (16), retrospectively reviewed 20 patients surgically treated for acute displaced fractures of the distal clavicle from 2002 to 2010. The indications for surgery were an adult patient with an acute fracture (less than 6 weeks old) of the distal clavicle consistent with Neer Type II. All patients were treated with superior locked plating augmented with suture cerclage or screw fixation into the coracoid when there were concerns with screw purchase in the lateral fragment. Union was assessed radiographically and function was reported in terms of American Shoulder and Elbow Surgeons (ASES) scores and motion. Sixteen of 20 patients were followed for a minimum of 1 year; four of the patients with less than 1 year follow-up were included. only for reporting of complications. The 16 patients were followed a minimum of 12 months (average, 30.7 months; range, 13–87 months). Union occurred in 15 of 16 (94%) patients. Average forward elevation and external rotation were 165.6° (range, 115°–180°) and 58.8° (range, 20°–90°), respectively. The average ASES score at the most recent follow-up was 79.0 (range, 33.3–100). Complications occurred in two patients. One patient developed an infected non-union and a second patient sustained a peri-implant fracture. Patients with acute distal clavicle fractures managed with superior locked plating demonstrated high union rates, good function, and low complication rates. This treatment method allows for the use of supplemental fixation in the form of suture augmentation or a coracoclavicular screw when necessary. In 2016, Shin SJ (17), prospectively evaluated 25 patients with unstable distal clavicle fractures who underwent anatomic plate fixation without coracoclavicular ligament augmentation. Clinical outcomes were evaluated using Constant and University of California-Los Angeles (UCLA) scores. Coracoclavicular distance was measured on plain radiographs. Bone union was achieved in all patients. Satisfactory clinical and radiologic outcomes were obtained regardless of fracture type. After operation, the mean coracoclavicular distance on the injured side was increased by 10% compared with the uninjured side. However, between the patients who showed an increased coracoclavicular distance >10% (Constant score, 89.4 ± 3.7; UCLA score, 32.6 ± 3) and the patients with increased coracoclavicular distance <10% of the uninjured side (Constant score, 88.7 ± 3.6; UCLA score, 31.9 ± 3), there was no statistically significant difference in clinical outcomes of Constant score (P = .934) and UCLA score (P = .598). This study concluded that in unstable distal clavicle fractures, precontoured anatomic plate fixation without coracoclavicular ligament augmentation showed satisfactory clinical outcomes and high union rates even with a small lateral fragment. Patients who had increased coracoclavicular distance also demonstrated satisfactory shoulder functional outcomes regardless of the fracture type. Therefore, anatomic plate fixation without additional coracoclavicular ligament augmentation can be considered one of the treatment options for unstable distal clavicle fracture.

Surgical technique Patient is kept in beach chair position with the affected arm in a mobile position. A transverse skin incision is made upon the clavicle with lateral extension to the lateral edge of the acromion. The AC joint capsule is not incised. After sharp dissection of the periosteum and debridement of fracture hematoma, the fracture was sparingly exposed. To gain anatomical reduction the fracture is temporarily reduced using two k-wires as temporary arthrodesis of the AC joint or using a reduction forceps. The position is checked using fluoroscopy. The AC joint was located by temporary insertion of a needle. The plate is centered onto the clavicular shaft and after confirmation of correct plate positioning in fluoroscopy, screw holes were consecutively drilled. This plate is anatomical and fits well to the contour of the lateral end of the clavicle. The time to union for precontoured locking plate was more as compared to distal radius plate with coracoclavicular fixation. So far, there have been limited studies of lateral clavicle fractures fixed with the help of locking LCP plates. In a small case series of Sajid et al (18), 4 cases of lateral clavicle fractures were treated with the help of different modalities of treatment including lateral clavicle locking with bone grafting, lateral clavicle locking plate alone, lateral clavicle locking compression plate system and Small Fragment Locking Compression Plate System and they recommended that the locking plate should be augmented with the coracoclavicular sling. Anderson et al (14) reported 13 cases of lateral clavicular fractures fixed with the locking LCP plate and concluded that superior locking plates provided high union rates along with good functions and low complications rates. In a comparative study done by Chunlin et al (19) the LCP plate was compared with the hook plate and in 66 patients (30 done by hook plate and 36 done by locking plate) it was seen that the clinical outcome was better in locking plate as compared to hook plate

- **Hook Plate Fixation**

Plate fixation of clavicular fractures is technically difficult because of the complex anatomy of the bone, with an S-shaped curvature and a cephalad to caudad bow. Also, with lateral clavicle fractures, the distal fragment is often of insufficient size and quality for the distal screws. Furthermore, during postoperative mobilization, the plate and screws have to withstand the earlier mentioned forces, often leading to premature loosening. The hook plate, first known as the Balser plate, was invented to solve these problems. Initial reports of this method of fixation were published in 1983 in German literature. In 1983, a hooked plate with an extension under the acromion has been developed to give more stable fixation for lateral end clavicle fractures. In 2002, Flinkkila et al. (20), retrospectively compared K-wire fixation and clavicular hook plate fixation in the treatment of unstable fractures of the distal clavicle. Kirschner wire (K-wire) fixation was used in 22 cases and a clavicular hook plate in 17. Shoulder symptoms and function were assessed using self-administered questionnaires devised by L'Insalata et al. and Constant scoring. Mean follow-up was 6.2 years in the K-wire fixation group and 2.0 years in the clavicular hook plate one.

The mean L'Insalata scores were 91 in both groups (92% and 93% of the contralateral side) and the mean Constant scores 84 (95%) and 90 (96%) for K-wire fixation and the clavicular hook plate, respectively. They conclude that shoulder symptoms were reduced and function restored to an adequate level by both methods, but complications were unacceptably frequent when K-wires were used. The clavicular hook plate was better in this respect and it is therefore recommended. 2005, Tambe et. Al (21) retrospectively assessed the union and shoulder function following hook plate fixation in 18 patients with Neer type 2 fractures of the lateral end of the clavicle. The average age was 40 (range 22–62) years, and the mean follow-up was 25 (range 6–48) months. Fifteen patients had acute fractures and the rest were non-unions. Complications included two non-unions, one following a deep infection. There were no iatrogenic fractures. Acromial osteolysis was seen in five patients who had their plates in situ. The average pain score at rest was 1 (range 0– 4), and the average pain score on abduction was 2.2 (range 0–5). The average Constant score was 88.5 (range 63–100). Patients were asked to rate their shoulder function; three rated it as normal, 11 as nearly normal and one as not normal. In conclusion of this study, they concluded that hook plate fixation appears to be a valuable method of stabilising Neer type 2 fractures of the clavicle, resulting in high union rates and good shoulder function but these plates need to be removed after union to prevent acromial osteolysis. In 2006, Haidar (22), reported the results of a group of 22 patients who underwent hook plate fixation for unstable lateral clavicle fractures between 1997 and 2004. The mean follow-up was 39 months. There were 4 significant complications. Twenty-one patients regained their preinjury level of activity, and 19 patients were satisfied with their outcome. In this study conclusion was hook plate fixation is an acceptable alternative method for the treatment of type II fractures of the lateral end of the clavicle.

In 2007, Muramatsu and et al. (23) used a new internal fixative implant, the AO clavicle hook-plate, for treatment of unstable fractures of the distal clavicle. This study described the operative procedure and the clinical results obtained, as well asdiscussion of the advantages and problems encountered. Fifteen consecutive patients with unstable fractures of the distal clavicle (Neer type II) were treated using AO clavicle hook-plates. The average age of patients was 47 years and there were 13 males and 2 females. The mean follow-up period was 15.5 months. Plain radiographs of clavicles were used to assess bony union. Functional recovery of the shoulder joint was assessed using the Constant–Murley scoring system. All fractures eventually achieved solid bony union within 4 months after surgery. Thirteen patients (87%) showed hook migration into the acromion. Clinical results were excellent with a mean Constant–Murley score of 89 points at final follow-up. AO clavicle hook-plates are useful fixative implants for unstable fractures of the distal clavicle. Static fixation was achieved and physiotherapy can be started immediately after surgery. Early removal of the implant is recommended however because hooks inserted under the acromion migrated into the bone in most cases. In 2010, Lee KW (24) and et al., in their prospective study assessed the clinical outcomes of an unstable fracture of the lateral end of the clavicle treated with an arthroscopic-assisted locking compressive plate (LCP) clavicular hook plate. Twentythree patients underwent arthroscopic assisted LCP clavicular hook plate fixation for unstable fracture lateral end clavicle. All patients achieved clinical and radiological union over a mean of 4.2 months (range, 3.4–5 months). Four patients (17%) showed some degree of acromial osteolysis. Three patients (13%) showed radiological signs of arthrosis of the acromioclavicular joint. In one patient, a second fracture (stress) was observed between the medial two screws of the plate without an additional injury. Five patients (22%) showed subacromial bursitis on dynamic ultrasonography. The mean Constant and Murley score was 91 points (range, 81–98). The average level of pain in the shoulder at rest and on abduction was 1 (range, 0–2) and 2.4 (range, 0–4), respectively. This study concluded that arthroscopic-assisted LCP hook plate fixation for the treatment of unstable fractures of the lateral end of the clavicle is not without complications. However, it is an acceptable alternative method that is easy to apply with good results. Furthermore, it prevents rotator cuff impingement, allows early mobilisation and maintains the acromioclavicular joint biomechanics.

Surgical Technique-The patients is operated in beach chair position under general anaesthesia with the arm on the affected side, freely moveable. A sagittal incision is placed just medial to the acromioclavicular joint over the fracture 7-8cm long. Full thickness skin flaps were prepared until the clavicle. The fracture is reduced; large comminuted fragments were temporarily fixed with K-wires and sometimes a lag screw was used. No repair of the torn ligaments was performed. Any interposed tissue was removed. Without opening the AC joint, the location of the joint is marked with a needle, and confirmed with fluoroscopy. The soft tissue dorsal to the AC joint was dissected and prepared for the insertion of the hook of the plate. The hook depth of 18 mm is fixed for all plates. The hook of hook plate is passed below the acromion. The shaft of the plate is placed on the superior aspect of the clavicle and checked for alignment. No excessive levering with the plate is performed to reduce the fracture. If excessive force or torque was needed, the reduction is verified and if needed altered. The clavicle portion of the plate is slightly bent to ensure central placement of the plate on the clavicle. The tip or hook portions are never bent. Before definitive fixation, plate position and full shoulder motion is verified using fluoroscopy. The plate is then secured to the shaft with 4 mm cortical screws approximating the plate to the clavicle. The screw length should be carefully observed in order to avoid neurovascular injuries. To ensure a stable fixation of the implant, at least two screws in the medial part of the plate were inserted. One or two screws can be used to fix the lateral fragments. If necessary, the distal metaphyseal end was secured to the plate through the anterolateral holes with cancellous screws. The wound is closed in layers over the plate.

The clavicle hook plate is an easy to handle solid plate that withstands forces that are applied to the fracture fragments. By design it keeps the lateral end of the clavicle reduced, hereby aligning the clavicle with the ligaments and minimizing movement at the fracture ends while it does not interfere with the rotational movement of the clavicle (25). The results published in several studies (26, 29) show good results in terms of bony union and in terms of shoulder function. Shoulder function is measured most frequently by the DASH and Constant-Murley scores. The DASH score is usually below 5 and the Constant-Murley score averages around 90. Non union occurs only seldom, below 10% in most series. The complications of hook plate fixation is related to the freely movable hook of the plate that is placed posterior to the AC joint, below the acromion, and above the supraspinatus tendon. Even though the design of the hook plate promotes fracture healing by keeping the fracture fragments reduced without interfering with the rotational movement of the clavicle, this design also leads to complaints due to mismatch between the hook of the plate and the diverse anatomy of the acromion. El Maraghy et al (30) demonstrated the mismatch between the plate and the subacromial space leading to several well described short term complications in an anatomic study. In 89% of the specimens the hook perforated the subacromial bursa, in 60% the tip had contact with the supraspinatus tendon and in 60% contact with the acromion was concentrated at the tip of the plate. These findings clarify the subacromial bursitis, the impingement complaints and the subacromial osteolysis respectively. Muramatsu et al (23) found it necessary to bend the hook in 77% of their patients, and found in most of their patients, migration of the hook after fixation. Their operative technique describes however, forcefully reducing the fracture using the plate as a lever. Impingement, subacromial bursitis and subacromial osteolysis on x-ray are signs of a mismatch between the plate and the anatomy of the patient. Several long term complications associated to the lateral clavicle fracture have also been described in relation to the use of this plate. These are ACJ arthrosis and extra articular ossifications. Due to the proximity of this plate to the ACJ, several authors discourage use of this plate(31)(27) When placed correctly, the plate does not violate the ACJ. However the vertical part of the hook passes behind the ACJ. This part of the plate could violate the joint if the plate migrates anteriorly but this is almost impossible when secured rigidly on the shaft.

- **Distal Radius T plate**

In 2008, Kalamaras (32), present a new technique and early observations using a distal radius locking T-plate normally used for fixation of distal radius fractures. Between July 2004 and May 2005, 9 patients with distal clavicle fractures (Allman group II, type II) were treated with open reduction and internal fixation by use of a titanium distal radial locking plate (Synthes) for fixation. The T-plate was flattened slightly at its T- junction to fit the clavicle, and the ends of the T were slightly bent downward to angle screws into the clavicle. Follow-up was performed in 8 of 9 patients after the procedure. In conclusion, the use of distal radial locking plates in this manner had not been described previously. It provided stable fixation, with minimal early complications.

The configuration of the locking screws seems to provide a stable construct in a small distal clavicular fragment. This was achieved without disturbance to the acromioclavicular joint, subacromial space, or rotator cuff. In addition, it was believed that routine removal will not be required. In 2009, Chao YU and el al. (33) observed the early clinical outcomes of the internal fixation with distal radius volar locking compression plate (LCP) in treatment of distal clavicle fracture. Six patients with unilateral distal clavicle fractures, identified as type II according to Neer classification system, including 4 males and 2 females, were treated with open reduction and internal fixation using a distal radius volar LCP. Bone union was evaluated by routine X-ray radiography, and shoulder joint function were assessed by Constant score system. All fractures achieved bone union at 6 to 8 weeks postoperatively, and Constant scores ranged from 95 to 100 at the postoperative 10 to 12 weeks. This study concluded that fixation of distal clavicle fracture with distal radius volar LCP demonstrates excellent effects of bone union with rarely early complications, thus providing a new technique to treat distal clavicle fracture. In 2009, Dagler B and et. al (34), evaluated the results of surgical treatment of displaced distal clavicle fractures using locked distal radius plates. Displaced distal clavicle fractures of 14 consecutive patients (11 men, 3 women; mean age 30 + or - 9 years; range 19 to 51 years) were treated using open reduction and locked distal radius plates. Except for two cases with late presentation, the mean time to surgery was 5.3 days (range 1 to 17 days). According to the Neer classification, fresh fractures were type II in 10 patients and type III in three patients. Shoulder examinations and functional evaluations were made at 3, 6, and 12 months postoperatively. Functional assessment included the Modified Shoulder Rating Scale and Constant score. All patients achieved full range of motion of the shoulder at six weeks postoperatively. The mean modified shoulder score was 18.7 + or - 1.5 and the mean Constant score was 95.4 + or - 3.0 at 12 months. None of the patients developed implant failure, loss of reduction, skin breakdown, or infection. In selected acute fractures and non-unions of the distal clavicle, excellent clinical results are easily achievable with locked distal radius plate fixation because it allows early shoulder movements without necessitating implant removal. In 2013, Martelschlager (35), assessed the clinical and radiological results after locking T-plate osteosynthesis with coracoclavicular augmentation of unstable and displaced distal clavicle fractures (Neer type 2). Thirty patients, treated between January 2007 and January 2010 were followed up after a median follow-up time of 12.2 months (range 4.7-37.2). The Constant and DASH scores were used to evaluate the clinical outcome, and anterior-posterior and 30° cephalic view radiographs were performed to assess the bony healing. In all patients, the fracture healing was achieved within the first 10 weeks after surgery. All patients regained good or excellent shoulder function and returned to previous occupation and activity levels. The mean Constant and DASH scores were 92.3 points and 6.2 points, respectively. No intra- or post-operative complication was observed within the time of follow-up. This study concluded that presented technique turned out to be a reliable method providing good results without showing severe complications. Surgical Technique--Operation required the beach-chair position with the injured limb freely mobile. A standard sabre-cut approach medial to the acromioclavicular (AC) joint was performed to visualise the fracture site and allow exposure of the coracoid process. The deltoid fascia was incised in line with the clavicle, if not already torn at injury. The fracture was reduced under direct visualisation and intraoperative fluoroscopy control. A 3.5-mm locking T-plate was applied for internal fixation and, if necessary, 2.0-mm cortical screws for fixation of large fragments. Coracoclavicular fixation was done by either 4mm cancellous cannulated screw or endobutton with mercilene tape. The deltotrapezoid fascia was reconstructed with absorbable sutures and the wound was closed in the standard manner. In literature (32)(36), the overall complication rate for this modality was comparatively very low as compared to other modalities of fixation of Neer type 2 fracture. There has been no interference with the acromioclavicular joint and no iatrogenic damage to the rotator cuff or impingement. As the distal radius plate fixation does not hamper the shoulder function as seen by hook plate, hence there is no need for implant removal surgery. Even though stabilisation and internal fixation using a hook plate is a common procedure and gives satisfactory results, there appears to be a significant rate of complications, such as delayed or non-union, implant failure and metaphyseal fracture.(22)

Post-operative Protocol

The limb is immobilised in a sling postoperatively. Early controlled passive mobilisation of the shoulder is started within 24h postoperatively. After discharge, the patients completes a physical therapy program involving passive and active mobilisation of the joint, with limitation of flexion and abduction of the shoulder joint to 90o for 2–6 weeks. Heavy labour and sports are limited for 12 weeks postoperatively.

Post-Operative follow up

Patients were followed up at 2 months and 4 months post Operatively and a 10 point VAS score, DASH Score and Constant-Murley Score was calculated at each visit. Radiographs were done to look for the signs of fracture union.

Conclusion

In unstable lateral end clavicle fractures, as such there is no gold standard treatment for fixation. Most of the old literature reviews are in support of hook plate fixation but the complications related with the hook around the AC joint and rotator cuff and second surgery for implant removal makes this fixation modality inferior in recent years. Recently, use of locking plates with or without coracoclavicular fixation is most widely accepted technique for fixation of these fractures as the complications are very less as compared to hook plate and also the faster union rates and hence faster recovery.

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