Condylar orientation plating in comminuted intraarticular fractures of adult distal humerus

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Abstract

Background: The condyles of the distal humerus have characteristic orientation in reference to the diaphysis. Anatomical reduction of the articular surface in intraarticular fractures of adult distal humerus does not always restore preinjury functional status. The purpose of this study was to determine the outcome of treating these fractures with technique of condylar orientation precontoured plating. The principle of the technique is to primarily restore the anatomical orientation of the reconstructed distal humeral condyle with the diaphysis of the humerus apart from anatomical reduction of fracture.

Materials and Methods: Seventy one consecutive patients with comminuted intraarticular adult distal humerus fractures were treated with the condylar orientation plates, which were specifically designed between 1999 and 2009. 43 fractures were Association for osteosynthesis (AO) type C3, 24 were C2 and 4 were C1. Six were open cases and two were of nonunion distal end humerus. On medial and posterolateral side of the distal humerus, precontoured Sherman plates were applied. Patients were followed up for a mean of 3 years. They were assessed clinically (using mayo elbow performance score [MEPS]) and radio-graphically.

Results: Sixty (84.5%) patients regained MEPS of 90 or more that is an excellent result (range of movement and functional status). One patient had nonunion with implant failure, and two patients developed heterotopic ossification. The mean MEPS was 95. Average extension and flexion was 15° and 133°. The result was graded as excellent in 60, good in 7, fair in 3 and poor in 1. At the time of most recent followup, 63 elbows were painless, and eight had mild pain.

Conclusion: Excellent pain free range of motion with a high rate of union can be achieved in comminuted intraarticular distal humerus fractures in adults with the use of condylar orientation precontoured plating technique. Condylar orientation is very important with perfect articular congruity in elbow motion.

Key words: Comminuted fracture, intraarticular fracture, distal humerus, humeral condylar fracture, precontoured plating

Mesh terms: Bone, humerus, fractures, fracture fixation, bone plates

Introduction

Despite anatomical reduction of the articular surface and stable fixation of the fracture, painless and satisfactory elbow function is not restored in a substantial percentage of patients in most series.[1,2] The distal humerus is unique among all the bones of the body by having the most complicated articular surface, which is part of a condyle that is rotated in three planes in relation to the diaphysis. The condyles project anteroinferiorly out of mid-sagittal plane of the humerus at an angle of 30°, known as anterior humeral angle[3,4] [Figure 1a]. In the coronal plane, the metaphysis is titled 6-8° laterally to form carrying angle [Figures 1b and 2a]. The elbow changes to neutral alignment at 90° flexion as the forearm moves from extension to flexion, but goes back to valgus in full extension. In addition, the distal humeral articular surface is 5-7° internally rotated (axially) in reference to the line connecting the epicondyles[3] [Figure 2b]. We hypothesized that the maintenance of these three-dimensional orientation of the distal humerus condyles with diaphysis is required to achieve optimum movement of the elbow. Most series have emphasized anatomical reduction of the articular surface for restoration of the elbow motion.[1,2,5-7] However, the elbow joint is unique as it can function even without an articular surface, as in interpositional arthroplasty. However, the principle of condyle-shaft orientation has not been studied so far. We have developed and used for last 10 years a fixation technique that is based on the principle of achieving stable fixation and restoring anatomical

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Access this article online	
Quick Response Code:	Website: www.ijoonline.com
	DOI: 10.4103/0019-5413.164046

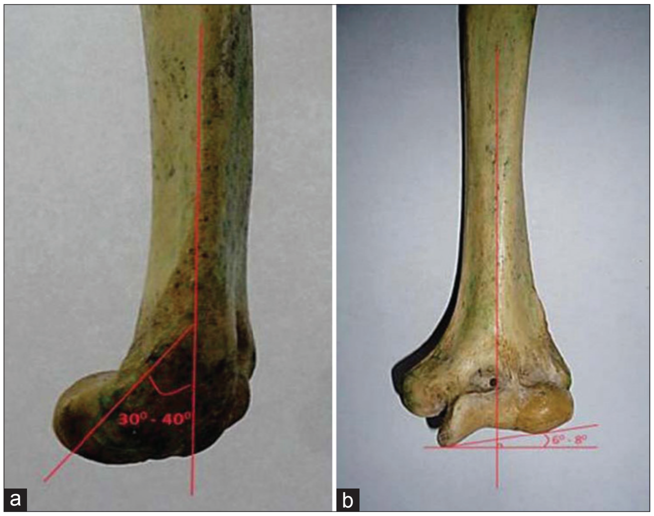

Figure 1: (a) Photograph of distal humerus from side showing anterior humeral angle (b) Photograph of distal humerus from front showing tilt of metaphysis in the coronal plane

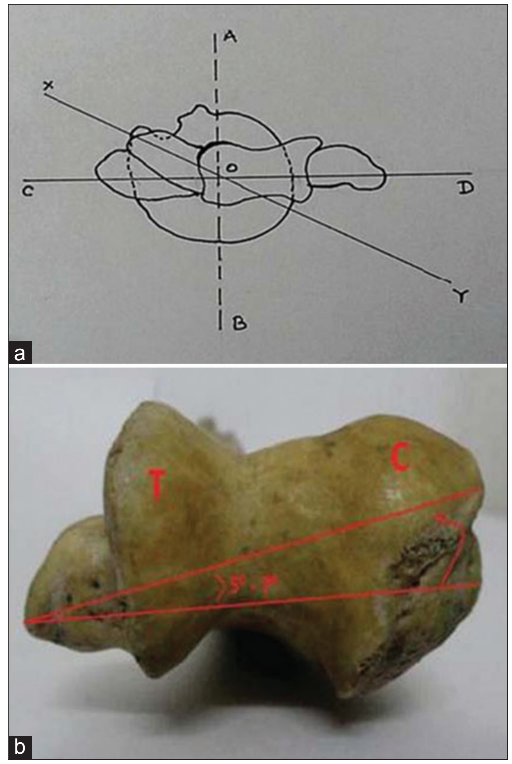

Figure 2: (a) Diagrammatic end view as seen from the lower end to show the relationship of the distal humerus with the head CD: Line passing through epicondyles. O: End on view axis of the shaft. YOB: Acute angle used to measure retroversion (b) Photograph of distal end humerus in the axial plane showing the distal humeral articular surface is 5-7° internally rotated in reference to the line connecting the epicondyles

condyle-shaft orientation by precontoured plates in addition to anatomical reduction of the articular surface. The medial precontoured plate maintains the coronal plane valgus alignment (carrying angle) and internal rotation of the humeral condyles. Precontoured posterolateral plate maintains the sagittal plane anterior alignment (anterior humeral angle) of the reconstructed distal humeral condyles. With this technique, less soft tissue dissection is required. The precontoured plating technique reduces the time of surgery and makes the procedure easier once adopted and practiced.

Materials and Methods

71 consecutive patients with comminuted intraarticular fracture of the distal part of the humerus were treated by the senior authors (SB and SS) using condylar orientation plates between December 1999 and June 2009. The procedure was used in all patients with distal humeral intraarticular fractures including some complex fractures because of extensive comminution, missing bone, poor bone quality, or any combination of these. While several patients had been referred for total elbow arthroplasty, they were treated with this technique of fracture fixation. The exclusion criteria were vascular injury, infected nonunion and ipsilateral long bone fracture in the same extremity. There were 42 male patients and 29 female patients with an average age at the time of the surgery 41.5 years (range 16-80 years). 31 fractures involved the right elbow and 40 the left elbow. The dominant upper extremity was involved in 33 cases. No patient had a preexisting pathological condition affecting the elbow. Mode of trauma was motor vehicle accident (n = 21); fall from height (n = 15) and domestic fall (n = 35). 6 fractures (8.5%) were open, Gustilo and Anderson[8] grade II (n = 2) and grade IIIA (n = 4). 8 patients had other associated injuries, had radial nerve injury (n = 3), side sweep injury (n = 1). Twenty seven elbows were treated after a delay of up to 10 days. The factors responsible for the delay in surgery included referral from another institution, prior surgery, medical comorbidities or a combination of these reasons. Two elbows had undergone operative intervention elsewhere before definitive fracture fixation by us. Three open fractures were stabilized with external fixator at the time of the first surgical debridement.

Elbow flexion and extension were measured with a long handle goniometer. Pronation and supination were estimated visually. The overall clinical results were rated with use of mayo elbow performance score (MEPS).

The preoperative radio graphs were assessed to classify the fracture according to the Association for osteosynthesis/ Association for the Study of Internal Fixation system. There were 4-C1, 24-C2 and 43-C3 fractures. Postoperative radiographs were evaluated for fracture union, change in hardware position and heterotopic ossification.

Operative procedure

All the patients were operated in the lateral decubitus position with the affected elbow flexed at 90° with the forearm hanging vertically over an elbow support. A tourniquet was used routinely. Wolfe and Ranawat[9] osteoanconeus flap approach was used in all elbows, particularly to avoid an olecranon osteotomy except in one which had an olecranon fracture. An osteoperiosteal (wafer) (osteoperiosteal flap comprising of insertion of triceps with a wafer of bone from olecranon for better healing) flap was carefully elevated for later closure. The olecranon was pulled outward for better visualization of the articular fragments by catching it through drill holes meant for later closure. (drill holes were made in the olecranon, a towel clip was used to hold the olecranon through the drill holes and pull it out so that the joint gets distracted and articular surface could be better visulalized for fracture fixation.Later during closure the same drill holes were used to anchor the osteoperiosteal flap to the olecranon).

Ulnar nerve was routinely identified and isolated and reflected from harm's way. The nerve was transposed anteriorly in all cases, where it was lying directly over the hardware.

The principle behind our method of surgery was restoring the condyle shaft orientation by the specially designed precontoured plates. In C 3 fractures (n = 43), we performed three dimensional computed tomography scan and planned our fixation accordingly.

315 LVM stainless steel Sherman plates (Calcutta Metallic Co., Kolkata, India) were chosen for fixation of the fractures. The Sherman plate is a low profile plate and stronger yet malleable than a reconstruction plate. One side of the plate is slightly concave to fit well on supracondylar ridge as well as flat surfaces. The plate is also very cost effective for our country. The plates are made and precontoured against different templates for different size humeri, male-female, large build-short build [Figure 3].

For medial side 10 cm or 12 cm long Sherman plates with 7-8 holes were used. The medial plate fits along the medial ridge with a sharp bend over the medial epicondyle to end just below it. This bend acts as a buttress and it allows one 4 mm long cancellous screw to purchase the opposite cortex. The medial plate incorporates 6–8° valgus alignment for the carrying angle. As the articular surface of the two condyles are not in the same coronal plane, the distal end of the medial plate was rotated about 5° internally and bent 30° anteriorly in relation with the humeral shaft. Because of rotation and bend, the medial plate is side specific. For posterolateral side 8 cm and 10 cm precontoured Sherman plate with 6-7 holes was chosen. The distal part of the plate is smoothly bent anteriorly to maintain the anterior humeral angle of 30°. The distal end of the plate just touches the articular surface of the lateral condyle to accommodate the radial head in full extension.

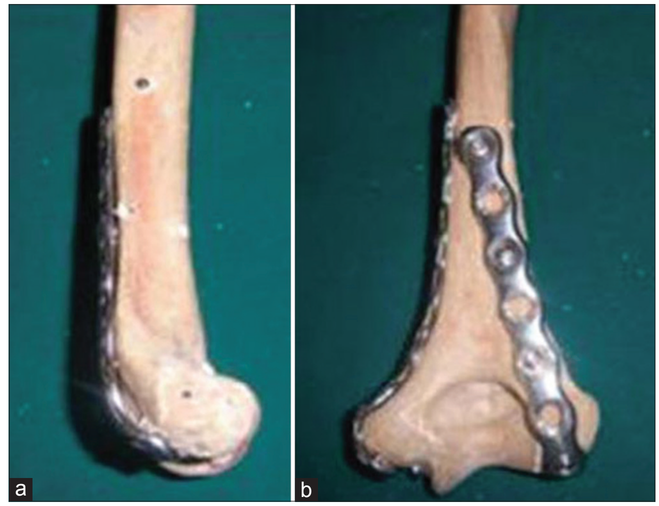

Figure 3: Photograph of distal humerus side view showing (a) condylar orientation plate placed on the posterolateral surface. It should end above the articular surface (b) Photograph of distal humerus front view showing medial and posterolateral plate in place

After exposure, the condyles were reduced and reconstructed with 4 mm cannulated cancellous screws. Particular attention was given to maintain the width of the trochlea by avoiding excessive interfragmentary compression so as to maintain the periarticular fossae for play of the olecranon and coronoid processes and the radial head.

The articular surface was reduced to an acceptable alignment. The small articular pieces were discarded. The indirect articular reduction achieved with the help of intact olecranon and radial head using as a template is accepted in this method of fixation.

Next the plates were fixed to the diaphysis and held with clamps. The medial precontoured plate was first fixed with the shaft over the medial ridge, and distal part of the plate was accommodated at the bottom of the medial epicondyle. It was then provisionally fixed with k wires. Because the Sherman plate is slightly concave, it fits into the medial ridge very well. While fixing the distal end of the plate just below medial epicondyle, partial detachment of the medial collateral ligament was required in some cases which were later carefully reattached.

Then the posterolateral precontoured plate was placed and fixed provisionally over the posterolateral curved surface which maintains the anterior humeral angle. The distal end of this plate ends just above the capitellar articular surface. By fixing the plates with the shaft (by clamps), distally a space is created between the two plates. The condyle is now placed into that space. While doing this, the medial trochlear ridge was maintained at an inferior position than the lateral trochlear ridge, to maintain the valgus angle and both the condyles were fixed with k-wires with special attention to their rotational alignment. Before final fixation of the fragments, it was checked whether the medial epicondyle was at a higher level than the lateral epicondyle, which confirms that correct internal rotational alignment has been restored. Later on k-wires were replaced with cannulated cancellous screws or solid 3.5 mm cortical stainless steel screws for definitive fixation. If needed oblique screws through or outside the plate were used to fix the opposite side shaft. This reorients the condyles with the shaft. Lastly, the plates are fixed with the shaft by cortical screws [Figure 4].

No cement augmentation was done in osteoporotic cases. In cases of bone loss, iliac crest bone graft was used liberally. Lag screw fixation was done as required, but trochlear width was always maintained. Special attention was paid to maintain the fossae at the supracondylar area, so that coronoid and olecranon can move freely without obstruction in full flexion and in full extension. The partially detached medial collateral ligament was carefully repaired. The triceps osteoperiosteal flap was reattached with the proximal ulna by absorbable suture (Vicryl™) through two-drill holes over proximal ulna.

Postoperative management

Immediately after closure, the elbow was placed in a posterior plaster slab to keep the elbow between 60° and 90° flexion. The initial rehabilitation was planned according to the extent of soft-tissue damage. When the fracture was associated with severe soft-tissue damage, as were most of the open fractures and high-energy closed fractures, the extremity was kept immobilized and elevated with the elbow in mid flexion for 3-7 days postoperatively. Otherwise, the initial dressing was removed after 2 days, and a light absorbent dressing was applied for ease of movement. A physical therapy program, including active and passive range of motion exercises was then initiated. All patients were permitted active use of the hand and were instructed not to lift anything heavier than a glass of water or telephone receiver for the first 6 weeks. No form of external protection, such as a cast or brace, was used by any patient.

Results

The mean followup of 47 months (range 6-120 months), 63 elbows were pain free, 8 were mildly painful. Elbow extension averaged 15° (range 0-60°), with 69 elbows (97%) having extension upto 30° or better. Flexion averaged 133° (range 90-150°), with 55 elbows (77%) having 130° of flexion. 55 elbows (77%) could extend to at least 30° and flex to at least 130°. The mean arc of flexion achieved was 118° [Figure 5]. At the most recent evaluation, the mean MEPS was 95 points (range 60-100 points). According to this score, the result was graded as excellent for 60 elbows, good for 7, fair for 3 and poor in 1.

Union of 70 fractures was achieved primarily. There was evidence of hardware failure in one of the elbows and the patient had developed nonunion. Heterotopic ossification developed in 2 elbows. The heterotopic ossification was severe requiring surgical excision to restore motion.

Discussion

The main challenge in the treatment of distal humerus fracture is to achieve stable joint with a good range of pain free movement. Despite the anatomical reduction of the articular surface, this cannot always be achieved. We have

Figure 4: (a) X-ray anteroposterior view of distal humerus with elbow joint showing comminuted intercondylar fracture (b) Postoperative radiograph anteroposterior and lateral views showing union of fracture

Figure 5: Clinical photographs showing range of motion

observed and hypothesized that distal humeral metaphysis has a peculiar orientation which is responsible for providing the elbow such range of motion. All fixation technique addresses the anatomical reduction of the articular surface and or stability of the construct. However, the principles of orientation of the condyles have not been applied so far.

We have used the Wolfe and Ranawat[9] osteoanconeus flap approach that provides excellent exposure and preserves the continuity of the triceps mechanism, which allows easy repair and rapid rehabilitation. The conventional approach is either olecranon osteotomy or Campbell triceps splitting approach. These approaches usually disrupt the extensor mechanism with possible risks of osteotomy nonunion, extensor weakness or later hardware problem.

The elbow is composed of two independent uniaxial joints allowing 2° of freedom. The instant center of flexion and extension for the elbow is at center of concentric circles formed by the lateral projection of the capitellum and trochlea of the distal humerus, which is about 2-3 mm in diameter and is located in the center of the trochlea when viewed from the lateral aspect. The axis of rotation of the elbow lies anterior to the humeral midline and on a line drawn along the anterior cortex of the humerus. The forward tilt of the articulation is beneficial.[4] Hence, it is vital to maintain the trochlea in that position while fixing the fracture. In our technique, the posterior plate is anteriorly precontoured to push the trochlea anteriorly so that center of flexion and extension is reconstructed. Most activities involving the elbow produce valgus force.[10] Hence, the natural inclination of elbow is valgus. In our technique, the valgus orientation of the condyles is recreated by the medial plate.

The contact surfaces of the elbow changes with different elbow positions. In full extension, the contact surfaces are on the inferomedial aspect of the ulna. In other positions, most of the joint contact occurs along the trochlear notch which passes from posterolateral to anteromedial.[10] This internal rotation is maintained by the medial plate which is twisted along its axis. During the fixation just fixing the proximal end of the plate with the shaft, achieves this rotation of the condyles. If the valgus alignment, anterior humeral angle and rotational alignment of the distal humerus with the shaft is not maintained, postoperative movement restrictions usually occur despite anatomical reduction of the articular surface.

The average range of movement in our series is 118°. Average flexion was 133° (range 90-150°). Average extension was 15° (range 0-60°). Published reports of range-of-motion (ROM) of distal humerus fracture ranges from 106°[11] to 122°.[12] Soon *et al*.[13] in their study reported 109.7°. We recorded comparatively good ROM. Excellent result in terms of MEPS was observed in 85% of cases after second procedure in 11 elbows. Current literature shows excellent result from 76%[14] in some series to 92%.[6] We believe that this range of motion and high rate of excellent MEPS are due to restoring the condylar axis to preinjury state. The anatomical restraints to the elbow motion include geometry of the joint, impaction of the olecranon process on the olecranon fossa and the radial head in the radial fossa.[8] Hence, while fixing we maintain these fossae and if required we put bone graft to fill any major defect. We neither put compression of the condyles nor do we do supracondylar shortening osteotomy.

The bone undergoes anteroposterior and posteroanterior cyclic force during elbow flexion and extension.[3] Dual-plate fixation has been described by several authors and seems to provide the most secure fixation. Helfet and Hotchkiss[15] studied the rigidity and fatigue performance of several methods including the dual-plate fixation. Although there are many fixation construct, the biomechanical behavior of the osteosynthesis depends more on plate configuration than plate type. They concluded that the dual-plate technique, with the plates oriented in two planes at 90° angles to each other, offered the most rigid and fatigue resistant construct especially in cases of comminution in which interfragmentary compression was precluded. Surgeon experience and preference may dictate the choice of a plate construct for this fracture configuration. In our technique as the interfragmentary compression was precluded to maintain the trochlear width, the plates were placed at 90° configuration for most rigid and fatigue resistant construct. The goal of osteosynthesis in our technique is to maintain the three key bony columns that is, medial and lateral pillars connected by the trochlea in proper alignment. Each small fragments need not be separately reduced which requires extensive soft tissue stripping and damage to the periosteum while at the same time the fragments act as bone graft while the defects remodel over time.

The precontoured plate we had used was 315 LVM stainless steel Sherman plate which is stiffer and stronger than the titanium, cost effective, easy to contour and low profile and it fits the crest of the bone as well as a flat surface. The dynamic compression plate is heavy and is not suitable for metaphyseal fractures where compression is not required for healing. The cancellous bone with extensive fracture surfaces usually heal. At the same time, one third tubular plate is too weak for fixation. Sherman plate resembles 3.5 pelvic reconstruction plates, but it is more malleable and is ideally suited for fixation in distal humeral metaphysis. At the same time, it allows the small fragments to be accommodated with their soft tissue attachment thus avoiding extensive dissection. If this complex condylar geometry is not maintained even after anatomical reduction of the articular surface considerable movement is not possible. The medial precontoured plate used in our technique not only maintains the orientation, but because the foot of the plate, which is bent over the medial epicondyle serves as a buttress for the comminuted fragments and a long screw is passed from the bottom of the plate to the opposite cortex.

The strength and stability of our technique is proved by the fact that we have observed only one nonunion in 71 cases. The single nonunion patient had undetected hypogonadism and severely reduced bone mineral density. All the fractures underwent uneventful union despite complexity of the fractures and intensive early rehabilitation.

Conclusion

Condylar orientation plating technique achieves a greater range of elbow motion with almost complete union rate compared to other techniques. The principle of condylar orientation is biological, avoids tissue dissection and is easy to perform.

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How to cite this article: Sarkhel S, Bhattacharyya S, Mukherjee S. Condylar orientation plating in comminuted intraarticular fractures of adult distal humerus. Indian J Orthop 2015;49:523-8.

Source of Support: Nil, **Conflict of Interest:** None.