

## Original Article

# Surgical techniques and clinical efficacy of micro locking plate in the treatment of capitellar fractures

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**Abstract:** Purpose: The surgical techniques and the clinical outcome of operatively treated capitellar fractures have not been clearly reported. The purpose of the present study was to explore the surgical techniques and clinical efficacy of micro locking plate in the treatment of capitellar fractures. Methods: From January 2012 to January 2015, 47 capitellar fracture patients were surgically treated. Based on the AO/OTA classification, there were 11 cases of B3.1 fractures and 36 cases of B3.3 fractures, while according to Dubberley classification, there were 7 cases of IA fractures, 9 cases of IB fractures, 11 cases of IIA fractures, 6 cases of IIB fractures, 9 cases of IIIA fractures, and 5 cases of IIIB fractures. Anteroposterior, lateral radiographs and computed tomography (CT) images were obtained in the course of preoperative radiological evaluation. All fractures were fixated by the micro locking plate using the vertical plate technique. Clinical, radiographic and elbow-specific outcomes were evaluated postoperatively. Results: Follow-ups with a mean duration of 18.1 months (range: 12-24 months) were carried out on all the patients. All fractures healed within an average of 11.4 weeks (range: 8-12 weeks). No complications were observed and the Mayo Elbow Performance score (MEPS) was 87.6 (range: 60-100), with 31 excellent results, 12 good and 4 fair results. Conclusion: Capitellar fracture is a specific type of elbow fracture. Open reduction with a posterolateral Kocher approach and fixation by micro locking plate using the vertical plate technique is a reliable method to achieve satisfactory elbow function in these fractures.

**Keywords:** Capitellum, fractures, mini-locking plate, internal fixator

## Introduction

Capitellar fracture is a rare intra-articular injury of the distal humerus, which can be easily misdiagnosed based on the X-ray [1], accounting for 0.5-1% of all the elbow fractures [2]. Since bones required for the internal fixation are inadequate during this type of fracture, it is rather difficult to perform the surgical treatment [1]. Although there are many surgical approaches and internal fixation patterns reported, a final conclusion is not achieved [3-5]. The aim of this retrospective study was to evaluate the results of micro locking plate in the fixation of capitellar fractures with a posterolateral Kocher approach in adults.

## Methods

### General data

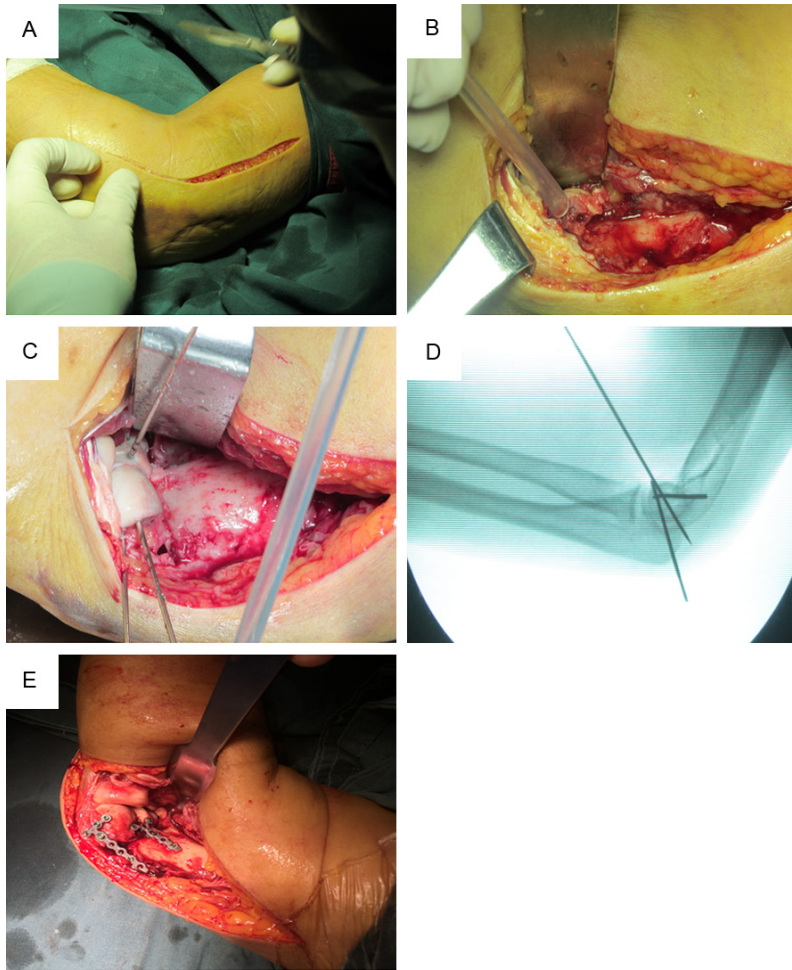
From January 2012 to January 2015, 18 patients with left lesions and 29 with right

lesions (47 patients, 31 males and 16 females, averaging 56.4 years) were studied. Forty-two injuries were caused by falls and 5 by falls from a height. All the injuries were closed lesions without neurovascular symptoms but 3 cases were complicated with elbow medial collateral ligament injuries. Based on the AO/OTA classification system, there were 11 cases of B3.1 fractures and 36 cases of B3.3 fractures, whereas according to Dubberley classification [6], there were 7 cases of IA fractures, 9 cases of IB fractures, 11 of IIA fractures, 6 IIB fractures, 9 IIIA fractures and 5 cases of IIIB fractures. Time from injury to surgery averaged 5.8 d (ranging from 2 to 15 d).

### Operative technique

Preoperative lateral radiography and CT imaging of the elbow were performed to determine the degrees of comminution, location and displacement status of the fractures and to design

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**Figure 1.** Surgical procedures: the posterolateral Kocher approach was applied (A); coronary fractures of the distal humerus were carefully exposed after layer-by-layer dissection (B); the anatomically reduced fractures were temporarily fixated by the K-wire (C); the intraoperative X-ray indicated satisfactory fracture reduction (D); the micro plate was used to fixate the fractures in an anterior to posterior manner and the pre-bent micro plate was placed lateral to the capitellum for support and fixation (E).

appropriate surgical plans. Patients were supinely positioned on the operating table with their injured limbs beside the trunk or on the side table. After general anesthesia or brachial plexus anesthesia, the elbow stability was analyzed first, followed by exsanguination of their hand, forearm and distal humerus by using a tourniquet at a pressure of 250 mmHg. Adopting the lateral epicondyle as the center, the posterolateral Kocher approach [7] to elbow was used and the humerus was surgically exposed from the lateral distal humerus to the posterior-lateral, with the distal interval ending 1-2 cm beneath the radial head and the proximal interval ending 5-7 cm above the level of elbow joint. The lateral distal humerus was

exposed after skin incision and the extensor and the whole layers of articular capsule anterior to the elbow joint were pronated from the lateral distal humerus. Dorsal interosseous nerve was usually not involved and therefore its anatomical exposure was not required. The main manipulation was conducted using a medium Hohmann contractor to insert the medial humeral column from beneath the anterior articular capsule at a 30°-45° flexion of the elbow joint. Debonding of the ulnar bundle of the radial collateral ligament was not required in this technique and when reducing the articular surface that required a larger exposure range, this ligament could be adequately lysed to fully expose the fractured capitellum and trochlea and remove the soft tissues and hematomas from the fractured end. The free capitellar and trochlear fractures were removed and the surrounding soft tissues and hematomas were debrided before the fixation. The tiny fractured fragments within the joint

that could not be fixated were preserved temporarily in case bone transplantation was required for some sites during the late stage of fixation. An articular surface displacement of  $\leq 1$  mm would not affect the function and stability of the elbow joint. For capitellum with trochlear fractures, we could adopt the on-table technique to fixate and then reduce after restoring them into the joint or fixate the trochlea first and then the capitellum. For Dubberley I and II fractures with intact posterior lateral condyle, the 1.0 mm Kirschner wire (K-wire) or 2.0 mm screw was used divergently from anterior to posterior in the fixation at the distal humeral articular surface in order to ensure the stability of rotation. It is noteworthy that iatro-

genic fracture of the capitellum should be avoided during screw implantation. The fixation wire or the screw should be indwelled in the flesh and a T-shaped - micro locking plate (3-4 holes at the proximal and 1-3 holes at the distal) could be perfectly fitted onto the capitellar articular surface for nonslip fixation. This plate should be placed laterally to the humeral trochlea, closely adhering onto the coronary sulcus that conjoins the capitellar articular surface and the humerus and maximally near the capitellum (Generally, the optimal situation is that the 2-3 distal holes of the T-type micro locking plate just cross over the coronary sulcus). Intraoperative examination of the elbow joint flexion should be performed to reduce the abnormal movements, obstructions and friction sounds. In addition, the T-type micro locking plate should not be implanted too distal, or the elbow joint function may be affected by capitulum radii during elbow flexion.

For Dubberley III fracture, i.e., fracture with posterior condylar comminution, it is difficult to apply the anteroposterior fixation with the K-wire or mini-screw, therefore, a stable bone bed is required to reduce the fractured articular surface. We reduced the fracture utilizing the anatomical relationship of the anterior articular surface as the criterion: 1.0 mm K-wire or 2.0 mm screw during the fixation applied at the distal humeral joint in a lateral to medial manner and then the T-type micro locking plate (3-5 holes at the proximal and 2-3 holes at the distal) was perfectly fit to the humeral lateral condyle for the support and fixation. If the fixation was not firm, another similar plate was perfectly fit onto the capitellar articular surface for the non-slip fixation in the same aforementioned position. The supporting plate should be placed lateral to the humeral lateral condyle. Excellent fracture reduction and appropriate screw length were intraoperatively confirmed in all the patients with the C-arm X-ray apparatus (**Figure 1**). The wounds were rinsed with normal saline and the elbow flexion and extension functions were examined for the obstruction caused by the protrusion of internal fixation. Unstable elbow valgus stress indicated ulnar collateral ligament injury, which required further inspection or repair as per necessity. Drainage should be adequate to prevent the heterotopic ossification induced by intra-articular hematocoele. The wounds were sutured layer by layer and bandaged while the elbow adjustable brace was adopted to fixate the lesioned limb at a flexion position of 90°.

### *Postoperative management*

Routine antibiotics were given 30 min preoperatively and until 24-48 h postoperatively, while oral medication of indomethacin was administered every 2 d postoperatively to prevent heterotopic ossification. Elbow adjustable brace was used immediately after the surgery to lock the injured elbow at the flexion position of 90°. However, when the pain was alleviated 2-3 d postoperatively, the brace was released to allow the active and passive flexion and extension activities within the range of 60°-110°. 2 weeks later the range of motion was gradually increased and the rehabilitation exercises for the forearm rotation function were initiated. 4 weeks postoperative X-ray observed the site and union status of the fracture further reinforcing the rehabilitation exercises for the elbow flexion and extension range as well as the forearm rotation function. Weight-bearing rehabilitation exercises of the upper limb were gradually initiated after confirming the fracture union at 9-12 weeks follow-up postoperatively.

### *Assessment of efficacy*

All patients were followed up once at 4, 8 and 12 weeks postoperatively and then once every 3 months. The follow-up included anterior and lateral X-ray films of the elbow joint, active and passive motion range of the elbow, and stability of the medial elbow joint. Location and healing status of the fracture, as well as the presence/absence of capitellar avascular necrosis, heterotopic ossification and traumatic arthritis were observed via the X-ray films (CT plain scan of the elbow joint could be performed when necessary). The criteria of fracture union were blurred or disappeared fracture line indicated by the X-ray films/CT images and loss of tenderness of the lateral elbow column.

At the last follow-up, we generally adopted the Mayo elbow performance score (MEPS) to evaluate the patients' elbow joint function subjectively and objectively, with  $\geq 90$  as excellent, 75-89 as good, 60-74 as fair, and  $< 60$  as poor. Meanwhile, we also recorded the flexion and extension range of the elbow joint, rotation range of the forearm, and stability of the medial elbow joint.

### **Results**

All patients received follow-ups averaging at 18.1 months (ranging from 12 to 24 months).



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**Figure 2.** A 75-year-old female patient suffering from capitellar and trochlear fractures (Dubberley IIIB) caused by falls when walking. Preoperative anterior and lateral X-ray films indicated coronary fractures of the distal humerus with obvious displacements (A, B); preoperative CT showed capitellar and trochlear fractures (C, D); anterior and lateral X-ray films (E, F) and CT images (G, H) taken 2 days postoperatively indicated anatomical reduction of the capitellum and trochlea, satisfactory internal fixation and excellent rehabilitation of the distal articular surface; functional examination performed 1 month postoperatively showed satisfactory rehabilitation of the elbow function (I, J).

Qualitatively, 42 patients achieved anatomical fracture reduction while 5 obtained quasi-ana-

tomical reduction. No neurovascular injuries appeared in the 47 patients and primary heal-

ing was achieved in all the patients 10-12 d postoperatively. The clinical fracture healing duration averaged at 11.4 weeks (ranging from 8 to 12 weeks). Three patients requested to remove the internal fixation implants after fracture union due to discomfort. X-ray results of the last follow-up showed that all the fractures were excellently healed without complications of loss of fracture reduction, internal fixation loosening or fracture, capitellar avascular necrosis, traumatic arthritis, or heterotopic ossification of the elbow.

During the last follow-up, patients' mean motion range of the elbow was 6° (0-10°) of extension and 118° (90-130°) of flexion and their MEPS score averaged 87.6 (range: 60-100). According to the Mayo elbow performance index, the measured outcome was 31 as excellent, 12 as good and 4 as fair, with an effective (excellent and good) rate of 91.5%. **Figure 2** shows the illustrative case.

### Discussion

Capitellum is located lateral to the distal humerus, protruding anteriorly and posteriorly, forming a 30° anteversion angle with the humeral long axis at the sagittal plane and a 6° valgus angle at the frontal plane. Lateral side of the capitellum is adhered to the radial collateral ligament; the common extensor origin and the capitellum forms the humeroradial joint wherein front and bottom of the radial head is covered by the articular cartilage. Trochlea is located in the center-medial portion of the distal humerus and medial to the capitellum. Trochlea has a boundary to the capitellum formed by integrating with the cartilaginous surface associated with the olecranon and forms into humeroulnar joint with the olecranon with cartilage coverage of nearly 360°. When the elbow is in the flexion position, the radial head rotates in the articular surface anterior to the capitellum. When the elbow is in the extension position, the radial head rotates in the articular surface inferior to the capitellum and the olecranon rotates around the trochlea.

When the elbow is in the flexion position and the forearm is pronated, external force to the upper limb is acts directly upon or along the forearm axis to the elbow, and the shear upward force may crush the capitellum via the

radial head, resulting in the coronary fracture of the distal humerus [3, 8]. The fractures contain the most part of or the entire capitellum, which may involve the trochlea via the connection between the capitellum and trochlea, while the fractured fragment is shifted forwardly and upwardly or even inverted at 90° [9]. Fracture type is associated with the intensity and speed of the damaging force.

Capitellar fracture is an intra-elbow fracture and most of the displaced fracture fragments lack obvious soft tissue adherence, and therefore the technique of ligament reduction cannot be applied [3, 4, 10-12]. The generally accepted opinion so far is that the surgical treatment is superior to the non-surgical treatment in multiple clinical efficacies [4, 13]. The comminuted bone fragments that are reducible and fixable should be maximally anatomically reduced and fixated rather than being removed. If the fixation is not firm; these fragments can be resected to avoid formation of free bodies that mechanically obstruct the joint activity and affect the rehabilitation of elbow function. On one hand, the postoperative blood supply of bone fragments with soft tissues like the joint capsule is excellent, which participates into and fastens the fracture union process, while on the other hand, fracture sites of the defective bone fragments are directly exposed to the articular cavity that may cause traumatic arthritis, myositis ossificans, and even joint instability in the long term, severely impairing the elbow function [14]. Ashwood [15] demonstrated that it is very important to maintain the firmness of reduced fracture as well as the stability of the elbow joint whilst small cartilages should be preserved intraoperatively for the reduced internal fixation. Jupiter [16] claimed that the rehabilitation of the coronary fracture of the distal humerus is associated with the restoration degree of its normal anatomical relationship.

Open reduction internal fixation was adopted for all the 47 patients in the present study. Small bone fragments should be maximally preserved during the anatomical fracture reduction for which the fractures were first fixated with the 1.0 mm K-wires temporarily and then with the 2.0 mm countersunk mini-screws or 3.0 mm countersinkable screws to maintain the integrity of the articular surface. For fractures with intact posterior condyles, the micro

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plate was perfectly fit onto the articular surface of the capitellum for the nonslip fixation. For fractures with posterior condyle involvements, one micro locking plate should be placed first at the lateral capitellum for support and fixation and the other one anterior to capitellum for nonslip fixation, i.e., the vertical plate technique has to be adopted. Multi-angle fluoroscopy should be performed to ensure that the reduction was excellent and the screws did not penetrate through the articular surface. Early post-operative active and passive elbow function exercises were conducted and no complications of the elbow myositis ossificans, traumatic arthritis or capitellar avascular necrosis appeared in any of the patient.

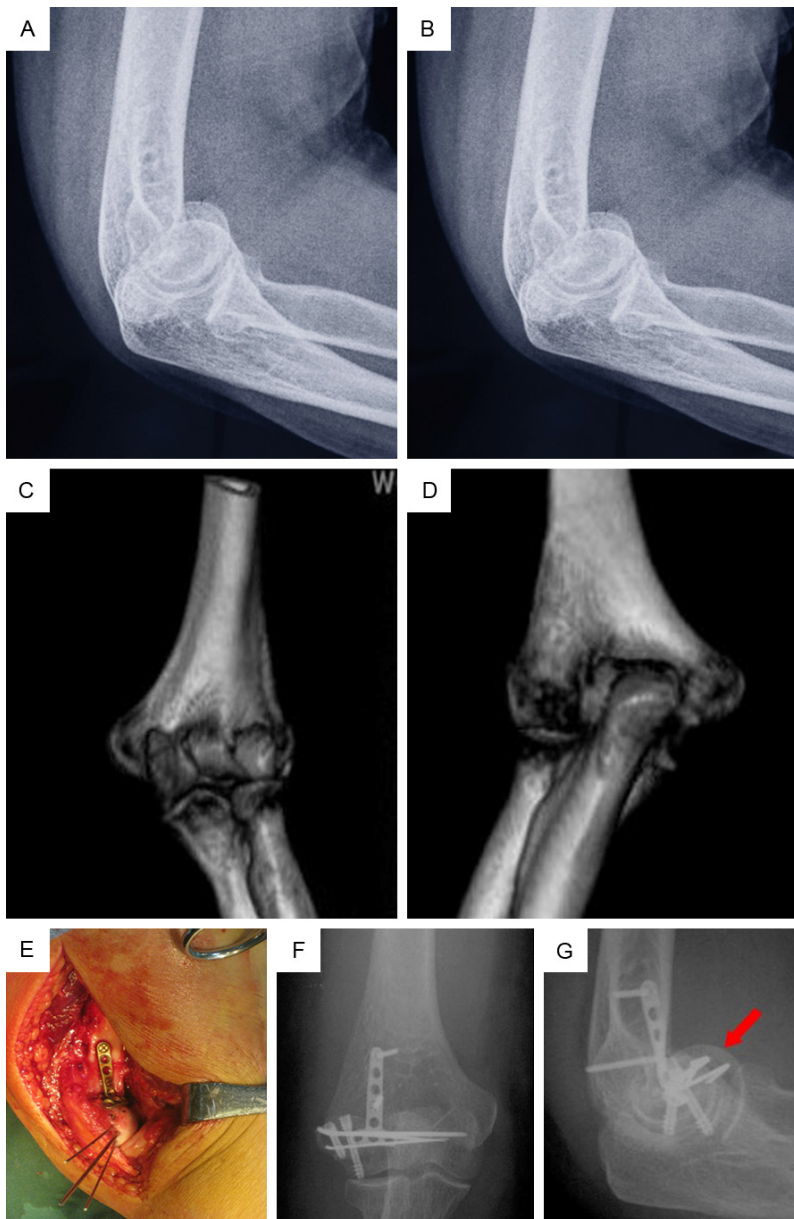
Singh [4] reported surgical approaches that included the anterior and posterior approach through the osteotomy of olecranon to the elbow. However, the classic posterolateral Kocher approach to the elbow is utilized in most of the shear fractures of the distal humeral articular surface. We hypothesize that selection of the surgical approach mainly depends on the fracture morphology, the shift direction and the surgeon's familiarity with the approach. The anatomical structure of the approach to elbow is complex, and may have risks of neurovascular damages. Although, the posterior condylar fractures can be exposed in the posterior approach through the osteotomy of olecranon to the elbow, the surgical trauma is massive and the risk of long-term heterotopic ossification in the elbow is high [16]. Nonetheless, the posterolateral Kocher approach to the elbow has advantages of excellent exposure, miniminvasiveness, high safety and low incidence of complications [14]. Sano reported good clinical outcomes in patients with coronary fracture of the distal humerus and who were treated by the open reduction and internal fixation [17]. The classic lateral Kocher approach was adopted in all the 47 patients included in the current study, wherein it excellently exposed, reduced and fixated the fractures, and caused no obvious elbow instability without additional surgical incisions.

The difficulties in the treatment of capitellar fracture are manifested in the following aspects: First, the incidence is low and thus it is hard to compare the clinical efficacy among different treatments; Second, damages in the young patients are usually caused by high ener-

gy injuries and often complicated with compound injuries of the elbow while the fractures are severely comminuted resulting in joint instability even after single bone structure repair. Furthermore, the damages in the elder patients are mostly low energy injuries and even if the fractures are not severely comminuted the bones are locally compressed and internal fixation loosening and fracture replacement may occur when the bone condition is poor; Third, for comminuted fractures, if the small bone fragments of the articular surface are preserved, it is difficult to perform the internal fixation and the occurrence of loosened fracture fixation may result into free fragmented bodies inside the joint, affecting its activity. Contrastingly, if the small bone fragments of the articular surface are not preserved, it will alter the shapes of the humeroradial and humeroulnar joint surfaces and lead to mismatched joints, causing elbow instability and traumatic osteoarthritis. Therefore, we believe that the surgical aim for capitellar fracture with or without trochlear involvements is restoring the smoothness and matching the corresponding humeroradial and humeroulnar joint surfaces, rigidly fixating the fracture and maintaining the reduction and stability of the joint in order to rehabilitate a variety of movements and elbow function as close as possible to the pre-traumatic performance. Therefore, the selection of internal implant and pattern is of crucial importance.

At present, single screw fixation is generally used as the main method of internal fixation. Sano [17] indicated that it would be difficult for the screw thread to completely penetrate through the fracture line and exert the effect of lag screws if implanted posteriorly in case of capitellar fracture with thin fracture blocks. If the fracture blocks were too small, the screws implanted posterior to anterior may damage the articular surface or split the fracture blocks and it would be hard to bury the screw thread under the cartilage surface. Ashwood [16] considered that the screws might damage the articular cartilage, result in chondronecrosis or osteolysis and affect the function of the elbow. Based on the knowledge of the injury mechanism and type of the articular fracture of the distal humerus, we believed that the previous single screw fixation cannot achieve rigid fixation. Since the fixation is not rigid enough, early effective function exercises that lead to the





**Figure 3.** A 63-year-old female patient suffering from capitellar and trochlear fractures (Dubberley IIA) induced by falls when walking down the stairs. Preoperative anterior and lateral X-ray films indicated coronary fractures of the distal humerus with obvious displacements (A, B); preoperative CT showed capitellar and trochlear fractures with intact posterior condyle (C, D); headless compression screw and micro plate were used intraoperatively (E); anteroposterior and lateral X-ray films (F, G) taken 2 days postoperatively indicated capitellar displacement and loss of reduction.

elbow dysfunction are not allowed. Although the nonslip plate can prevent capitellar fracture from sliding, effectively cover the comminuted fracture blocks and avoid sliding of the entire lateral condylar fracture, only stability and firmness of the coronary fracture are ensured when effective fixation and early functional rehabili-

tation exercises cannot be achieved for comminuted posterior condyle or incomplete humeral condyle fracture. Moreover, as we increased the sample size and prolonged the follow-up of patients with the distal coronary fracture who underwent nonslip plate treatment, we found that the nonslip plate could neither ensure stability and firmness of the fracture in patients with osteoporosis (**Figure 3**) nor the patients could perform early functional rehabilitation exercises. Therefore, for the 12 out of 47 patients with posterior condylar comminution, a micro locking plate was placed first at the lateral capitellum for support and fixation on the basis of K-wire and screws and another anterior to capitellum for nonslip fixation, i.e., the vertical plate technique was adopted. On one hand, fixation with K-wire or screw after anatomical reduction of the comminuted fracture can ensure the integrity and consistence of the comminuted fracture and on the other hand, internal fixation with micro locking plate from 2 planes can not only prevent anterior sliding and provide lateral support but also achieve the effective coverage of the comminuted fracture blocks and multi-angle fixation. This further ensures the stability and firmness of the fracture,

maintains the matching and stability of the reduced articular surface, facilitates the conduction of early functional rehabilitation exercises of active and passive extension and flexion, and maximally restores pre-traumatic elbow function. Follow-up of the 47 patients in the current study suggests stable internal fixa-

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tion without displacement, excellent fracture position, successful early rehabilitation exercises and satisfactory restoration of the elbow function in all the patients.

In conclusion, capitellum involved in the comminuted fracture of humeral lateral condyle are difficult to be diagnosed basing on X-ray films, and CT images are required to determine the lesion scope and degree of comminution of the fracture. The classic posterolateral Kocher approach can adequately expose the range of fracture and successfully complete the surgical procedures. The micro locking plate is used to provide lateral support and anterior fixation for the anatomically reduced fracture based on the fixation with K-wire and mini-screw. Early post-operative function-restoring exercise is initiated and the short-term clinical follow-up indicates satisfactory efficacy. However, due to the small case sample size and short follow-up duration, this technique necessitates further clinical and biomechanical research for a wider clinical application or finite element analyses with a longer follow-up duration and a larger sample size.

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The research was approved by the Ethics Review Committee of xi'an Hong-Hui Hospital, Xi'an, Shaanxi, China and written informed consent was obtained from all participating patients.

### Disclosure of conflict of interest

None.

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