

Fixation of the Various Coronal Plane Fracture Fragments, Including the Entire Coronoid Process, in Patients with Mayo Type IIB Olecranon Fractures - Four Methods for Fixation

Abstract

Background: We introduce several methods for fixation of unique Mayo type II olecranon fractures with the coronal plane fragment (CPF) including the entire coronoid process and report the radiological and clinical results through a case series. **Materials and Methods:** 12 patients were operated using this method with a mean age of 44 years. CPFs were fixed with concurrent fixation by a locking plate screw for the olecranon in three patients (method 1), cerclage wiring in six patients (method 2), a mini plate in two patients (method 3), and a double-locking plate (method 4) in one patient. We accessed the fragment through an additional medial coronoid approach after identifying the olecranon fragment through a dorsal approach (methods 1–3). In method 4, the CPF was fixed through a dorsal approach between the comminuted metaphyseal fragments. **Results:** With the exception of one patient with delayed union, all patients had achieved union at 3-month followup. The mean flexion extension arc was 125°. The mean pronation/supination was 72.5°/71.7° (range, 60-80°/60-80°). The mean visual analog scale score for elbow pain was 0.92 (range, 0-2), and the mean Mayo Elbow Performance Score was 86.7 (range, 80-90). The mean Disabilities of the Arm, Shoulder, and Hand score was 10.2 (range, 4-14). There were no major complications. **Conclusion:** A thorough preoperative understanding of the fragment patterns and preparation of tools for adequate reduction and fixation are necessary for satisfactory clinical and radiological outcomes. However, further comparative trials of conservative management versus surgery for CPF fixation, and any differences in outcomes according to the CPF fixation options, are required.

Keywords: Cerclage wiring, coronal plane fragment, coronoid process, olecranon fracture

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Introduction

Olecranon fractures are not uncommon, and account for about 20% of proximal forearm fractures.¹ Successful functional outcome is directly correlated with anatomic restoration of the articular surface, repair of the elbow extensor mechanism, restoration of joint stability and motion, and prevention of stiffness and other complications. Several options have been introduced for the treatment of olecranon fractures, and overall radiological and clinical outcomes have been reported to be good to excellent.²⁻⁷ Plate fixation is the best treatment for olecranon fractures as associated with severe comminuted fractures, oblique pattern fracture distal to the center of the trochlear notch, with concurrent coronoid process, and associated with the elbow fracture dislocation.⁸⁻¹⁰ Among the

comminuted olecranon fractures, we have noted unique fracture patterns of Mayo type IIB fractures with concurrent coronal plane fragment (CPF) including the entire coronoid process.

On the other hand, as noted by Wiegand *et al.*,¹¹ several classification systems for olecranon fractures have been described, but none were universally accepted by 2010. Each classification system is subject to interrater variability, and none has been shown to be more reliable than the others. In addition, unique Mayo type IIB fractures with the CPF were difficult to explain in several well-known classification systems.¹²⁻¹⁴ Recently, Giannicola *et al.*¹⁵ proposed a new and comprehensive classification, the proximal ulnar and radial fracture dislocation comprehensive classification system (PURCCS). The PURCCS helps identify the main lesions of each injury pattern, and the associated

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therapeutic algorithm helps select correct surgical strategies. However, this classification showed that the majority of cases had combination fracture patterns of the proximal ulna and elbow dislocation.

The fractures of Mayo type IIB with CPF in our study did not present as the fracture dislocation type and additional injuries related to elbow fracture dislocation, for example to ligamentous structures and the radial head, were absent. Instead, the fragments between the olecranon and CPF were too various to fix using certain fixation tools. Therefore, we introduce several methods for fixation of unique olecranon fractures, including CPF, and report the radiological and clinical results through a retrospective case series.

Materials and Methods

Patient selection

Our institutional review board approved the patient registry (IRB No. 2016-08-036), and all patients provided informed consent before participation. Ultimately, 12 patients with concurrent Mayo type IIB fractures with CPF were included in study. Out of 129 patients diagnosed with olecranon fractures between March 2008 and February 2013.

The inclusion criteria were: (1) an olecranon fracture (Mayo type IIB) in which the CPF included the entire coronoid process; (2) a unilateral olecranon fracture; (3) preoperative CT for evaluating fracture fragmentation; (4) surgery performed by a single surgeon; (5) availability of complete medical records and radiological data collected at the time of injury; and (6) at least a 2-year followup.

Patients with the following characteristics were excluded: (1) symptomatic degenerative lesions of the ipsilateral upper extremity; (2) any other concurrent skeletal injury in the ipsilateral upper extremity (from shoulder to wrist); (3) fracture dislocation injuries with any lesions of ligamentous injury and radial head, coronoid process, and interosseous ligament; (4) Mayo type I and III fractures; (5) concurrent neurovascular injuries around the elbow; and (6) open fractures.

Demographic data

Four of the patients were male and eight were female. Their mean age at the time of injury was 44 years (range 19–69 years). The mechanisms of injury were slipping, falling from a height (direct blow), and traffic accidents. Seven patients sustained injury to the dominant-side elbow. The selection of the most appropriate method for fixation of various types of fracture depended on the fracture location and shape and the extent of comminution in the olecranon area [Table 1]. The CPF was fixed with concurrent fixation by a locking plate screw for olecranon in three patients, cerclage wiring in six patients, a mini plate in two patients, and a double-locking plate in one patient [Table 2]. General anesthesia was given in six patients and brachial plexus block was used in six patients.

Operative method 1: Concurrent coronal plane fragment fixation using the locking plate for olecranon fractures

Each patient was placed in the supine position, the upper extremity was prepared and draped in standard orthopedic fashion, and the elbow was flexed across a pillow placed on the patient's chest. A tourniquet was placed on the upper arm. After a longitudinal incision was made on the posterior cortex of the ulna, the olecranon fragment was provisionally fixed to the distal metaphysis. Then, we accessed the fragment, including the coronoid process, through a medial coronoid approach^{16,17} with changes in arm position. With the elbow resting on the table in a position of external rotation, we performed provisional fixation of the CPF using K-wire or Kocher forceps to the distal humeral articular surface and ulnar diaphysis. Finally, an adapted olecranon (Synthes, Oberdorf, Switzerland) or periarticular plate (Zimmer, Warsaw, IN, USA) was placed carefully on the reduced bones, then the cortical screw was inserted at the intact diaphyseal area, and the CPF was fixed using two or three locking screws to maintain anatomical reductions in both the olecranon fragment and CPF [Figures 1 and 2].

Table 1: Treatment options for fixation according to the features of the fragment

Features of the fragment of the entire coronoid process	Fixation method used in the current study
Fragment of the entire coronoid process	
Including the base above the line of connecting the olecranon tip and the base of coronoid process in lateral simple radiographs	Concurrent fixation by locking screw
Including the base below the line of connecting the olecranon tip and the base of coronoid process in lateral simple radiographs with extended fracture to distal diaphysis	Cerclage wiring
Including the base above/below the line of connecting the olecranon tip and the base of coronoid process in lateral simple radiographs with comminution at the anteromedial facet of coronoid base (around sublime tubercle)	Mini plate
Including the base above/below the line of connecting the olecranon tip and the base of coronoid process in lateral simple radiographs with comminution at the dorsal surface of olecranon	Double plating (medial/lateral additional plate)

Table 2: Basic demographic data of the patients

Case	Age	Gender	Injury mechanism	Mayo classification	Lesion/dominancy	Fixation tool for coronal plane fracture	Bone graft
1	60	Female	Fall from height	IIB	Right/dominant	Concurrent fixation by locking screw	No
2	39	Male	Fall from height	IIB	Left/nondominant	Concurrent fixation by locking screw	No
3	47	Female	Fall from height	IIB	Left/nondominant	Concurrent fixation by locking screw	No
4	25	Male	Slipped	IIB	Left/nondominant	Cerclage wiring	No
5	69	Female	Slipped	IIB	Left/dominant	Cerclage wiring	No
6	60	Female	Fall from height	IIB	Right/dominant	Cerclage wiring	No
7	19	Male	Traffic accident	IIB	Right/dominant	Cerclage wiring	No
8	33	Female	Traffic accident	IIB	Right/dominant	Cerclage wiring	No
9	48	Female	Slipped	IIB	Left/nondominant	Cerclage wiring	No
10	47	Female	Traffic accident	IIB	Left/nondominant	Mini plate	No
11	38	Male	Fall from height	IIB	Right/dominant	Mini plate	No
12	43	Female	Fall from height	IIB	Right/dominant	Double plating (medial and lateral additional plate)	Anterior iliac bone

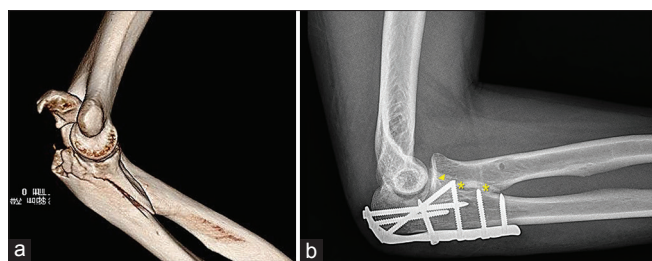


Figure 1: Concurrent coronal plane fragment fixation using a locking plate for olecranon fractures (Method 1) in a 39-year-old man who fell from a height (Case 2). (a) Mayo type IIB olecranon fractures with coronal plane fragment. (b) Coronal plane fragment was reduced by two cortical screws (asterisks) and a locking screw (arrowhead) placed concurrently during plating of the olecranon

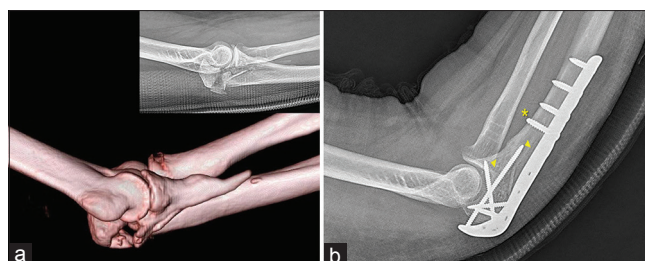


Figure 2: Concurrent coronal plane fragment fixation using a locking plate for olecranon fractures (Method 1) in a 47-year-old woman who fell from a height (Case 3). (a) Mayo type IIB olecranon fractures with coronal plane fragment. (b) Coronal plane fragment was reduced by a cortical screw (asterisk) and two locking screws (arrowheads) placed concurrently during plating of the olecranon

Operative method 2: Additional cerclage wiring

The anesthetic protocol, patient position, and surgical procedure were identical to those described in operative method 1. However, the large CPF extending into the more distal diaphyseal area would be amenable to obtaining sufficient fixation strength during the initial cortical screw insertion. In addition, in cases with another fragment extending from the proximal metaphysis, wiring for CPF was followed by the use of a dorsal locking plate [Figure 3].

Operative method 3: Additional small locking plate for coronal plane fragment fixation using the locking plate for olecranon fractures

In some patients, even with medial fascial exposure from the posterior ulnar cortex, accurate reduction of CPF was not easy due to the fractured fragment being between the coronoid process and the articular surface. Through an additional medial coronoid approach,^{16,17} the CPF was elevated using the anterior capsule as a hinge and the fragments inhibiting reduction of the CPF were debrided. Then, small locking plates (Aptus® Radius; Medartis,

Basel, Switzerland) were used for fixing the CPF before dorsal olecranon plating [Figure 4].

Operative method 4: Direct approach through the comminuted dorsal cortex –“open the roof” method

In further rare cases, there was another sagittal split fragment in the dorsal cortex of the ulnar metaphysis. Method 4 was applied for the most complex type of fracture among our patients with an additional concurrent sagittal split fragment in the posterior area. Through a dorsal approach for traditional olecranon fracture, we temporarily opened the just-posterior comminuted fragment of the CPF, like a roof. Then, after debridement of the hematoma and bony debris, we placed and fitted the CPF at the humeral articular surface, considering it as floor. Thus, the medial and lateral walls were reinforced by both sides of the locking plate screws in an interdigitating pattern. Then, we closed the roof (previously opened posterior fragment) after packing the morselized and grafted bone, finally fixing the olecranon fragment to the solid CPF-medial and lateral wall using the long olecranon plate [Figure 5].

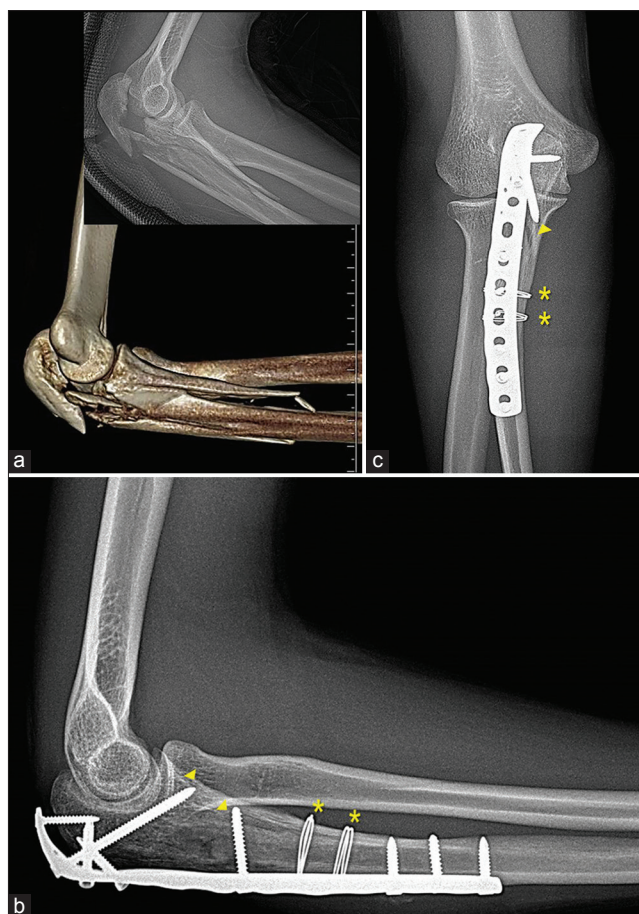


Figure 3: Concurrent coronal plane fragment fixation using cerclage wiring for olecranon fractures (Method 2) in a 25-year-old man who slipped (Case 4). (a) Mayo type IIB olecranon fractures with coronal plane fragment. (b and c) Coronal plane fragment was reduced by two cerclage wires (asterisks) and then fixed by a cortical/locking screw (arrowhead) during plating of the olecranon. Fixation was maintained until the final followup at 26 months without any displacement and was properly united in lateral and anteroposterior simple radiographs, respectively

Radiological evaluation

Patients were followed up at 2, 5, and 9 weeks, and then at 3, 6, 12, and 24 months, postoperatively. At each visit, we routinely took simple radiographs of the affected elbow to evaluate immediate postoperative reduction, especially of the CPF, progression of bony union, and development of heterotopic ossification, including bony spurs or loose bodies. Union was defined as more than three regions of bony continuity among the lateral, medial, anterior, and posterior cortical aspects of the proximal ulna, as seen on anteroposterior, lateral, and both oblique radiographs. The presence of delayed union or nonunion was evaluated. Such union achieved after 6 months was defined as delayed union. Nonunion refers to either lack of bridging across the fractures, of at least three of four cortices, at 6 months or longer from the time of surgery, or no radiographic changes for 3 consecutive months in association with clinical findings consistent with nonunion (e.g., inability to bear weight through the affected extremity, pain on palpation, or pseudomotion).

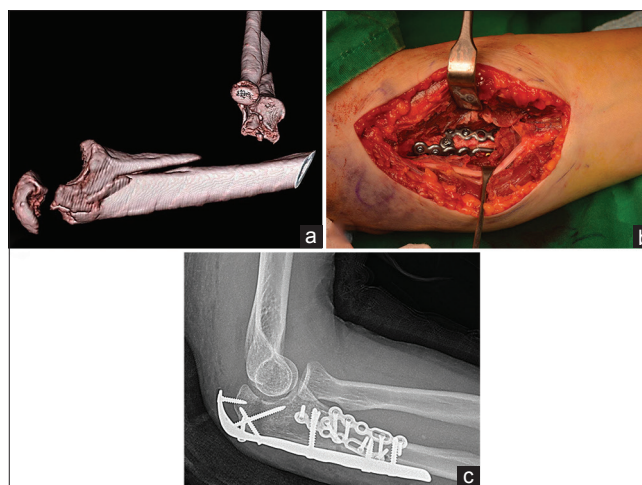


Figure 4: Concurrent coronal plane fragment fixation with mini plates (Method 3) in a 47-year-old woman injured in a traffic accident (Case 10). (a) Mayo type IIB olecranon fractures with coronal plane fragment. (b and c) Coronal plane fragment was reduced by two mini locking plates through a medial coronoid approach and then fixation of the olecranon fragment was performed

Clinical evaluation

Clinical outcomes of all patients were evaluated at the final followup. Range of elbow motion was checked, and the degree of pain was evaluated using a visual analog scale. Functional outcomes were evaluated at least 2 years postoperatively using the Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder, and Hand (DASH) score.

Postoperative management

After surgery, all patients were fitted with splints allowing flexion (50°–90°); these remained in place for 2 weeks in patients treated via methods 1 and 2, and for 4 weeks in those treated via methods 3 and 4. Next, continuous mechanical passive elbow motion was performed every other day for 3 weeks. Careful gradual active flexion was permitted from 5 weeks (7 weeks in patients treated via methods 3 and 4) after surgery, with all patients wearing hinged elbow braces for 1 month. Patients were permitted to return to normal daily activities, as tolerated, at 3 months.

Results

All evaluations were done at least 2 years postoperatively with a mean followup of 31.2 months. With the exception of one patient with delayed union, all patients had achieved union in both the olecranon fragment and CPF at the 3-month followup. In the one patient with the CPF treated by cerclage wiring, the CPF was finally consolidated at 9 months despite proper union of the olecranon. The mean arc of flexion/extension of 12 elbows was 125° ± 6.2°. The mean rotational ranges were also satisfactory with pronation/supination of 72.5° ± 7.5°/71.7° ± 5.7°, respectively. The mean visual analog scale score for

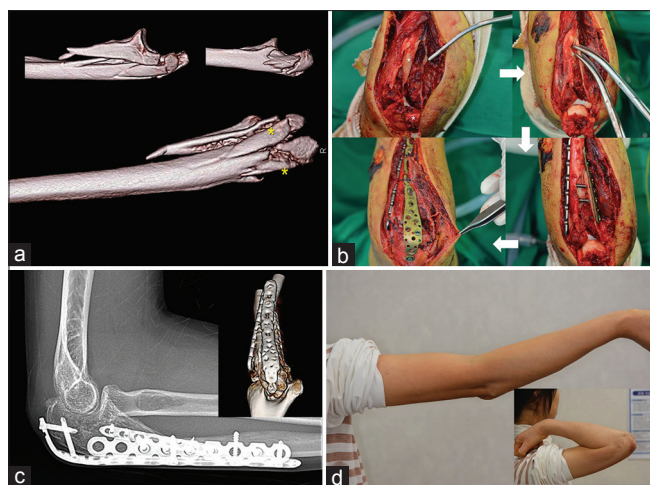


Figure 5: Concurrent coronal plane fragment fixation by medial/lateral double plating (Method 4) in a 43-year-old woman injured by falling from a height (Case 12). (a) Mayo type IIB olecranon fractures with coronal plane fragment and other fragments (asterisks) split in the sagittal plane. (b) The comminuted fragments ("roof") in the distal metaphyseal area were identified after hematoma removal and debridement. Coronal plane fragment was reduced by Kocher forceps, with contact of the coronoid process to the distal humeral articular surface after "opening the roof." Thus, medial and lateral walls were reinforced by both sides of the locking plate in an interdigitating pattern. Then, we closed the cuboid (i.e., the roof, or previously opened fragment) after packing the morselized and grafted bone, finally fixing the olecranon fragment to the solid cuboid using the long olecranon plate. (c) At the final followup, well-consolidated fragments without definitive arthritic changes in the elbow joint were observed. (d) The flexion extension arc was 130° at the final followup

elbow pain was 0.92 ± 0.7 , and the mean MEPS was 86.7 ± 3.9 . The mean DASH score was 10.2 ± 3.4 . In one patient treated with an additional small locking plate, sensory abnormalities of the ulnar nerve distribution were normalized at 2 months postoperatively. A temporary superficial infection limited to around the olecranon was seen in one patient which was resolved with intravenous antibiotics. Degenerative bony spurs were found in two patients around the tip of olecranon during the followup period, but these were subclinical issues. Hardware removal was performed in three patients due to symptomatic prominence of the olecranon plate [Table 3].

Discussion

In our experience, olecranon fractures with CPF including the entire coronoid process are not common. None of our 12 cases presented with fracture dislocation even with the presence of coronoid process injury. In addition, all the CPFs had a wide, mountain-shaped base. However, the Mayo, Schatzker, and AO classification system did not accurately identify this fracture pattern. The significance of the CPF in olecranon fractures has not been reported previously, whereas the significance of coronoid process fracture in elbow fracture dislocation has been well documented (the so-called "terrible triad"). This is likely because these fragments were regarded by surgeons as less of a priority for rigid fixation compared with olecranon fractures. Similar to the debate regarding the necessity of

coronoid process fixation in cases in which elbow stability was established after repair/reconstruction of ligaments or the radial head in terrible triad elbow injuries,¹⁸ rigid fixation of the locking plate for the olecranon fragment only may be suggested by intraoperative physical tests of stability or radiological inspection under an image intensifier. However, under anesthesia, the contraction tone generated by the brachialis would be minimal, and the intact joint capsule would also be attached just a few millimeters from the coronoid process presenting with a minimally displaced CPF. Other reasons for the failure to recognize the significance of CPF in olecranon fractures would be technical difficulties in treatment. That is, in cases lacking comprehensive plans for fixation of any other fragments, including the CPF, concurrent fixation on both the anterior and posterior sides through opposite approaches would not be easy.

Morwood *et al.*¹⁹ introduced another olecranon fracture pattern, involving sagittal split and requiring additional fixation using a method similar to that described in the current study. They used an additional orthogonal small plate or cerclage wiring, because the proximal fragment had a concurrent sagittal split in the same plane as that of the standard plate screws designed for olecranon fixation. However, these injuries could be well fixed and maintained by a conventional dorsal approach for olecranon fractures and exposure of the lateral muscle fascia. On the other hand, we used a medial coronoid approach,^{16,17} for CPF in all except one patient treated with operative method 4, after identifying the features of olecranon fractures on the same posterior skin incision. These fixations for CPF were complex in several respects. First, arm position on the table could be changed carefully just after provisional fixation for CPF, to the flexed arm position on the pillow for fixation of olecranon fragments. In addition, during predrilling for the first cortical screw and the subsequent locking screws of the olecranon plate in the distal meta-diaphysis area, the CPF should be penetrated by bit with maintained as properly reduced state by forceps or clamps, for exact screw fixation (method 1), even when firmly reduced by cerclage wiring or an additional plate (methods 2 and 3). Finally, some patients had comminuted fragments on the opposite posterior side of the cortex from that of the CPF. These areas are relatively weak compared with the CPF, and therefore accurate reduction could be performed only with a small locking plate (method 3). However, locking plates manufactured for the coronoid process were too small to fix the CPF in our series, and therefore we used longer plates designed for the dorsal cortex of the distal radius after proper bending to fit the contours of the CPF.

Over the years, we have noted the outcomes of patients with untreated CPF in olecranon fractures transferred from other institutes. Although long term followups were not performed, most of them presented with less satisfactory results than our patients. Bony unions of CPF were observed, but the distal

Table 3: Radiological and clinical outcomes

Case	Postoperative period (months)	Radiologic findings	Flexion (°)	Extension (°)	Arc (°)	Pronation (°)	Supination (°)	VAS	MEPS	DASH	Degenerative bony spur	Heterotrophic ossification	Complication
1	24	Union	140	-20	120	70	70	2	85	14	Yes	No	No
2	30	Union	125	-5	120	70	80	1	90	12	No	No	No
3	44	Union	130	0	130	80	70	1	90	10	No	No	Symptomatic hardware prominence
4	26	Union	130	0	130	80	70	2	85	12	No	No	No
5	40	Union	120	-5	115	70	80	0	90	4	No	No	No
6	30	Union	125	-10	115	70	70	1	90	10	No	No	Superficial wound infection
7	28	Union	130	0	130	60	70	0	80	4	No	No	No
8	30	Union	135	-5	130	60	60	1	80	14	No	No	No
9	36	Delayed union	125	0	125	80	70	1	85	12	No	No	Symptomatic hardware prominence
10	30	Union	135	-10	125	80	70	0	85	12	No	No	Transient ulnar nerve symptoms
11	28	Union	140	-10	130	70	70	1	90	8	No	No	No
12	28	Union	135	-5	130	80	80	1	90	10	Yes	No	Symptomatic hardware prominence

MEPS=Mayo Elbow Performance Score, DASH=Disabilities of the Arm, Shoulder, and Hand, VAS=Visual analog scale

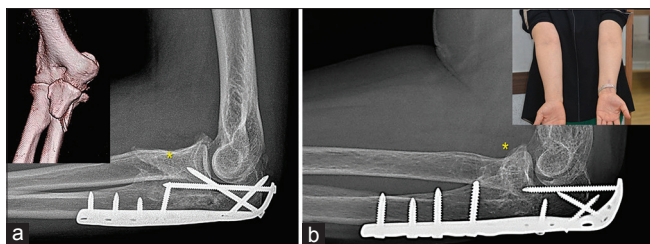


Figure 6: Cases with malunion of coronal plane fragment (asterisks) in Mayo type IIB fractures. All patients were treated at other institutes and were not included in our study. (a) Flexion was limited to 100°. (b) Grossly, varus deformity was the main complaint due to malunion of the coronal plane fragment (asterisk) and loss of medial buttress of the coronoid process despite a satisfactory range arc (130°)

portion of the fragment was displaced anteriorly due to the effects of the brachialis and hinge of the anterior capsule. Most of the patients complained about the decreased range of flexion. In addition, other patients showed varus elbow deformity after injury, caused by malunited CPF with loss of a medial buttress effect of the anteromedial facet of the coronoid process [Figure 6].

The present study had three major limitations. First, this was not a comparative trial. Although olecranon fractures are relatively common injuries, accounting for approximately 10% of upper-extremity injuries in adults, concurrent CPF patterns are significantly rare.²⁰ Thus, longer followup periods or multicentric trials are needed to obtain sufficient data to compare the effectiveness among our different methods, or between these methods and other possible options. Moreover, more comprehensive classification, to cover the various different patterns of olecranon fracture, would be helpful in guiding treatment according to the presence of specific fragments. Finally, we could not identify lesions associated with acute elbow instability, such as of ligaments or the radial head, due to our small patient population. However, this could be investigated, with respect to biomechanics, in further studies performed in larger numbers of patients.

Conclusion

In conclusion, olecranon fractures with concurrent CPF are not common injuries. A thorough preoperative understanding of the fragment patterns and preparation of the tools for adequate reduction and fixation are necessary for rigid fixation and early range of motion. In addition, we reported satisfactory clinical and radiological outcomes, although the number of cases in this series was small. However, a comparative trial of conservative management versus fixation for CPF using our method, or comparison of differences in outcome according to the fixation options for CPF during olecranon surgery, is expected in the future.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have

given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest

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