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The Challenge of Trans-Ulnar Basal Coronoid Fracture-Dislocations: A Surgical Strategy Based on the Pattern of Coronoid Fracture

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Background: The rarity and complexity of trans-ulnar basal coronoid fracture-dislocations pose significant challenges in treatment. This study aimed to categorize these fractures based on coronoid fracture patterns and propose tailored surgical approaches for each type. Additionally, we evaluated the functional and radiological outcomes among the patients managed using our treatment algorithm.

Methods: A total of 19 patients who underwent open reduction and internal fixation for trans-ulnar basal coronoid fracture-dislocations between March 2018 and October 2022 were enrolled in this study. These patients were classified based on the coronoid fracture patterns associated with olecranon fractures: type 1 involved anteromedial facet (AMF) fractures, type 2 encompassed coronoid base and body fractures, and type 3 involved a combination of types 1 and 2. We made a midline longitudinal dorsal incision to facilitate the provisional fixation of the olecranon fragment to the distal metaphysis using a locking plate. Subsequently, we employed the over-the-top (type 1) and Taylor–Scham (type 3) approaches for direct coronoid process fixation with buttress plating. Type 2 fractures were approached via medial fascial exposure from the posterior ulnar cortex or through the olecranon fractures, and subsequently fixed with miniplates and screws. Bony union and joint articulation were assessed via plain radiographs, and functional outcomes were evaluated using range of motion and the Mayo Elbow Performance Score.

Results: Among the 19 patients, 3 had type 1 fractures, 14 had type 2 fractures, and 2 had type 3 fractures. All fractures exhibited solid osseous union without subluxation or dislocation. The average flexion and extension arc was 119.47° ± 20.88°, with a mean flexion of 127.37° ± 13.37° and an average flexion contracture of 7.89° ± 10.04°. The average Mayo Elbow Performance Score was 82.63 ± 12.51 points. Qualitatively, patient outcomes were excellent in 5 patients, good in 9, and fair in 5.

Conclusions: Most of our patients presented with easily approachable coronoid base and body fractures. However, in AMF fractures of the coronoid process, a direct medial approach is required for buttress plating. We believe our study helps provide useful guidelines for making appropriate decisions in trans-ulnar basal coronoid fracture-dislocations .

Keywords: *Coronoid fracture, Proximal ulnar fracture, Elbow fracture and dislocation*

Complex fracture-dislocations involving the proximal ulna pose significant treatment challenges and often yield unsatisfactory results.[1-3] Historically, orthopedic surgeons classified these injuries as either Monteggia-like injuries or trans-olecranon fracture dislocations.[2,4] However, there is a scarcity of specific information regarding elbow fracture-dislocations with complex proximal ulnar fractures, particularly those involving coronoid fragments.[1,2,5,6]

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While several studies have shown the crucial role of the ulnar coronoid process in maintaining elbow stability by acting as a vital buttress that prevents the ulna from posterior translation,[3] research indicates that fractures resembling Monteggia-type injuries show a remarkably higher rate of unsatisfactory outcomes in cases accompanied by coronoid fragment fractures. Thus, effectively reducing and fixing the coronoid process is a challenging yet essential surgical task that must be addressed in cases of complex fracture-dislocation of the proximal ulna.[1,2,6-8]

Recognizing this challenge, a recent study proposed a coronoid-centric classification system for proximal trans-ulnar fracture dislocations.[9] This classification divides these fractures into 3 patterns according to what the coronoid remains attached to: trans-olecranon fracture-dislocations (the olecranon is fractured but the coronoid remains attached to the ulnar metaphysis); Monteggia-variant fracture-dislocations (the ulnar metaphysis is fractured but the coronoid is still attached to the olecranon); and trans-ulnar basal coronoid fracture-dislocations (the coronoid is not attached to either the olecranon or the ulnar metaphysis). Surgical treatment goals in trans-ulnar basal coronoid fracture-dislocations involve restoring the articular surface of the ulnohumeral joint, which is achieved by reestablishing the relationship between the olecranon and coronoid.[3,10] Olecranon fractures are easily assessed through a longitudinal incision on the posterior cortex of the ulna and addressed using a precontoured congruent locking olecranon plate. However, the surgical approach to the coronoid varies based on accompanying bony injuries and patterns of coronoid fragments. For instance, the coronoid may be approached either medially or through the existing olecranon fractures. Alternatively, a medial or lateral facial exposure approach via a single posterior incision can also be used to access nearly the entire joint, which is particularly useful for large coronoid fragments.[3] Despite the utility of these approaches, determining the most effective approach for trans-ulnar basal coronoid fracture-dislocations can be challenging in clinical settings.

This study aimed to classify trans-ulnar basal coronoid fracture-dislocations based on coronoid fracture patterns and propose tailored surgical methods for each type. Additionally, we evaluated the functional and radiological outcomes of patients managed according to our treatment algorithm.

METHODS

This retrospective case series study was approved by the Institutional Review Boards of the 2 participating institutions (Chung-Ang University Hospital: IRB No. 2401-014-19505 and Chung-Ang University Gwangmyeong Hospital: IRB No. 2401-130-003). Owing to the retrospective study design using existing data from medical records, informed consent was not required.

Between March 2018 and October 2022, a total of 252 patients underwent open reduction and internal fixation of olecranon fractures at our institutions. Among them, 19 patients who underwent open reduction and internal fixation for trans-ulnar basal coronoid fracture-dislocation were enrolled in this study. The inclusion criteria were as follows: (1) trans-ulnar basal coronoid fracture-dislocation, characterized by the absence of coronoid attachment to either the olecranon or the ulnar metaphysis; (2) preoperative computed tomography (CT)-based evaluation of fracture fragmentation; (3) complete medical records and radiological data collected at the time of injury; and (4) follow-up for at least 1 year. The exclusion criteria were the presence of any other concurrent skeletal injury in the ipsilateral upper extremity (from the shoulder to the wrist) and concurrent neurovascular injuries around the elbow.

Patients received treatment based on our surgical algorithm if their fracture patterns fell into the following classifications, which took into consideration the patterns of coronoid fractures associated with olecranon fractures: (1) type 1 injuries were anteromedial facet (AMF) fractures of the coronoid (AMF fractures according to the O'Driscoll classification); (2) type 2 injuries were coronoid base and body fractures (basal fractures according to the O'Driscoll classification); and (3) type 3 injuries were a combination of type 1 and type 2 injuries (Fig. 1). The study group comprised 11 men and 8 women, with an average age of 51 years (range, 19–80 years). The mean follow-up duration was 15 months (range, 12–24 months). Two experienced hand surgeons (JSL and HSJ) independently evaluated the CT images. One observer repeated the analysis after a 2-month period to assess the intraobserver reliability. Intraobserver and interobserver reliability of classification of trans-ulnar basal coronoid fracture-dislocations was assessed using weighted kappa analysis. Landis and Koch[11] previously categorized kppa values of 0.00–0.20 as indicating slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; and 0.81, almost perfect agreement.

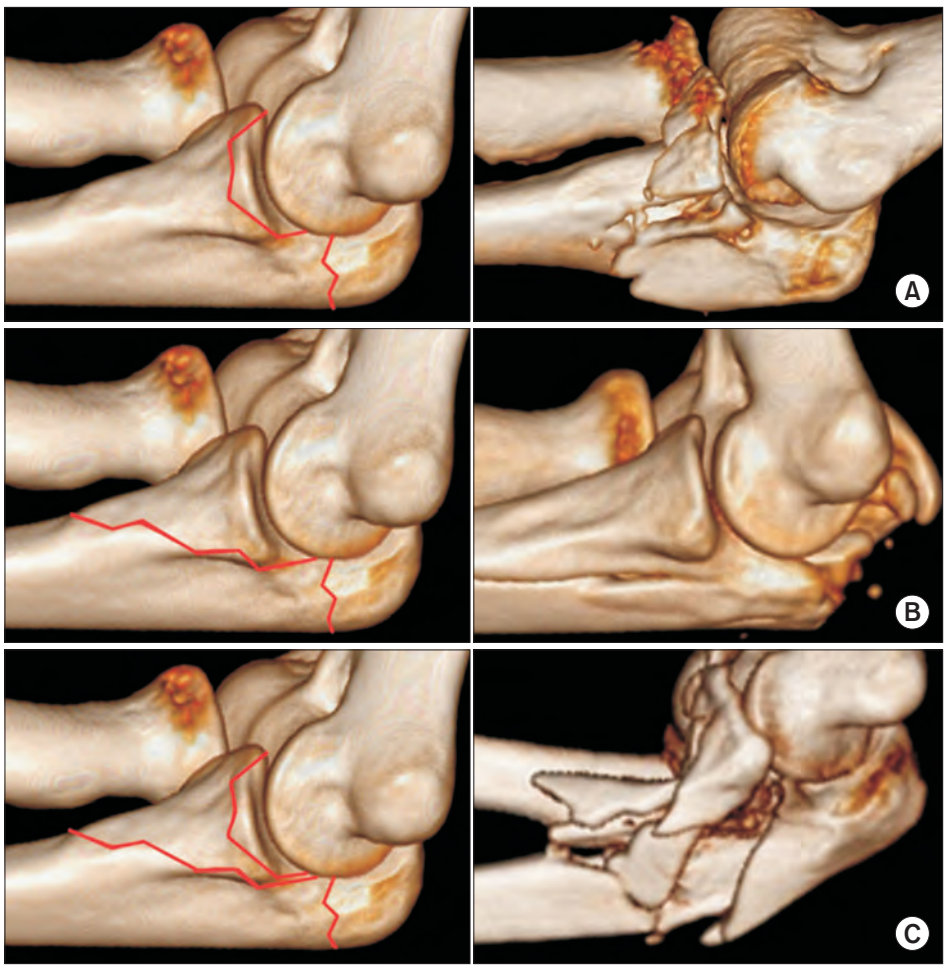

Fig. 1. Classification of trans-ulnar basal coronoid fracture-dislocations based on the pattern of coronoid fractures. (A) Type 1 (anteromedial facet fracture of coronoid). (B) Type 2 (base and body fracture of coronoid). (C) Type 3 (combined type 1 and type 2 injuries).

Surgical Procedure

All surgeries were performed by 2 experienced hand surgeons (JSL and HSJ) under general anesthesia or a brachial plexus block. Briefly, each patient was placed in a supine position, and the elbow was flexed across a pillow placed on the patient's chest. Following this, a tourniquet was placed on the upper arm, and after a midline longitudinal posterior incision was made, the olecranon fragment was provisionally fixed to the distal metaphysis or diaphysis using a locking plate (Acumed). Subsequently, we accessed the coronoid fragment through a posterior dorsal incision. Notably, a medial approach was used to treat type 1 fractures. For type 1 fractures, an over-the-top approach was used to approach the coronoid process. In this approach, the anterior margin of the flexor-pronator mass (FPM) and medial supracondylar ridge of the humerus were identified. FPM was then slightly splitted on its medial side, approaching AMF to avoid median nerve injury. In addition, the humeral origin of FPM was slightly detached from the medial epicondyle during FPM splitting, and periosteal dissection was performed mainly medially to adequately expose AMF.[12] Fracture fragments were addressed and fixed temporarily with a Kirschner wire (K-wire), followed by the use of a mini-plate (Jeil Medical or Synthes), which was slightly bent to fit the contour of the coronoid process and used to buttress the fractured fragments (Fig. 2). For type 2 fractures, because the coronoid fragment was larger and occasionally extended to the distal diaphyseal area, the medial fascial exposure was performed from the posterior ulnar cortex or through the olecranon fracture in a straightforward fashion before temporary fixation of the olecranon by a locking plate.[8] Following this, a mini-locking plate, cerclage wiring, or locking screws from the olecranon plate were used to fix the coronoid process (Fig. 3). Type 3 fractures were addressed using the Taylor-Scham approach.[13,14] The muscular origin of the flexor digitorum profundus, the ulnar head of the flexor digitorum superficialis, and the deep head of the pronator teres were elevated. Dissection was performed anteriorly and proximally until the anterior margins of the coronoid and sublime tubercles were reached. Fractures were anatomically reduced and temporarily fixed with a K-wire, with a focus on large

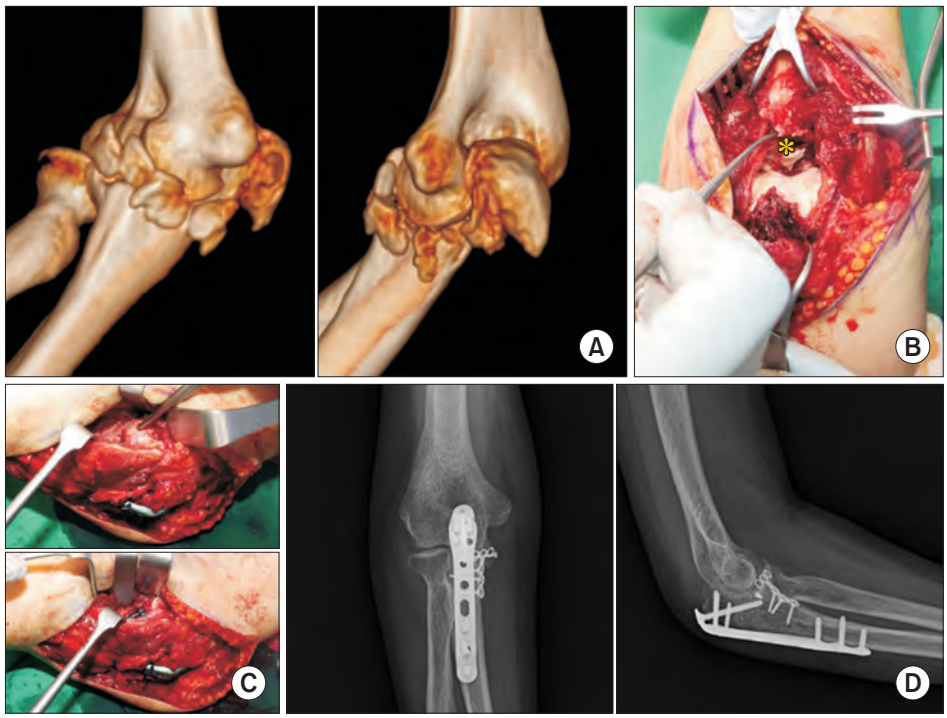

Fig. 2. A 70-year-old woman classified as having a type 1 trans-ulnar basal coronoid fracture-dislocation. (A) Three-dimensional computed tomography reconstruction of the type 1 trans-ulnar basal coronoid fracture-dislocation. (B) Anteromedial facet fragment (AMF) fractures (asterisk) were seen through the posterior approach. However, it was hard to reduce and fix through this approach. (C) After reduction of olecranon fracture, AMF fracture was anatomically reduced through the over-the-top approach with mini-plate. (D) Postoperative anteroposterior and lateral radiographs at the final follow-up.

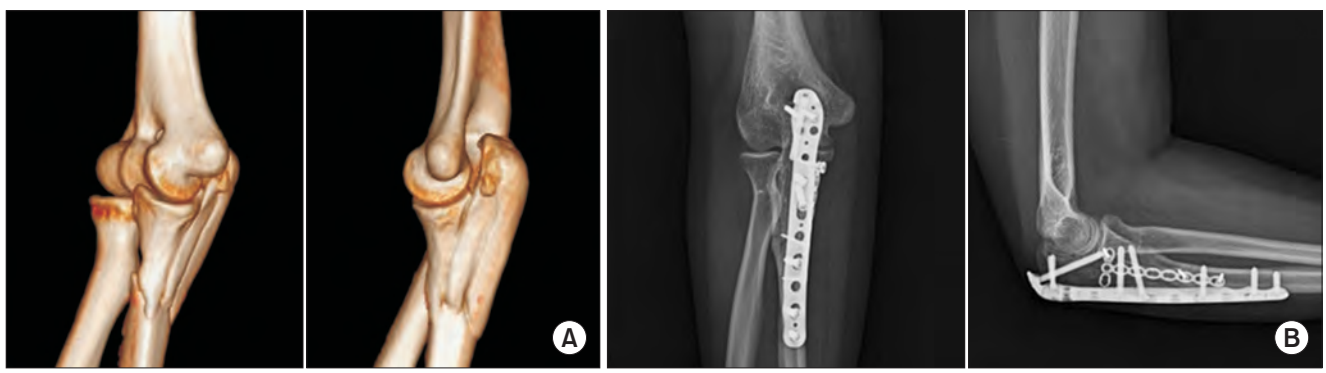

Fig. 3. A 25-year-old woman classified as having a type 2 trans-ulnar basal coronoid fracture-dislocation. (A) Three-dimensional computed tomography reconstruction of the type 2 trans-ulnar basal coronoid fracture-dislocation. (B) Postoperative anteroposterior and lateral radiographs at the final follow-up.

fragments. After the template was applied, a mini-locking plate was cut and bent to fit the AMF contour, while taking into considerations the figure and size of the fragment. Large fragments were fixed with cerclage wires and screws (Fig. 4). After fixation of coronoid fragments, additional screws were inserted in the dorsal olecranon plate. In type 3 fractures, anterior subcutaneous transposition of the ulnar nerve was performed during the final stage of surgery.

Postoperative Management

Postoperatively, the elbow joint was immobilized in a long arm splint in a neutral position and the elbow at 90° of flexion. At postoperative 2 or 3 weeks, the splint was removed and a removable brace was applied to facilitate exercises. During this period, gentle, active-assisted exercises were allowed. At 6 or 8 weeks, the removable brace was discontinued. A return to occupational activities was permitted 3 months postoperatively.

Assessment of Radiological and Clinical Outcomes

Bony union and occurrence of heterotopic ossification were retrospectively evaluated based on the findings of the anteroposterior and lateral radiographs at the final follow-up. Union was defined as the presence of more than 3

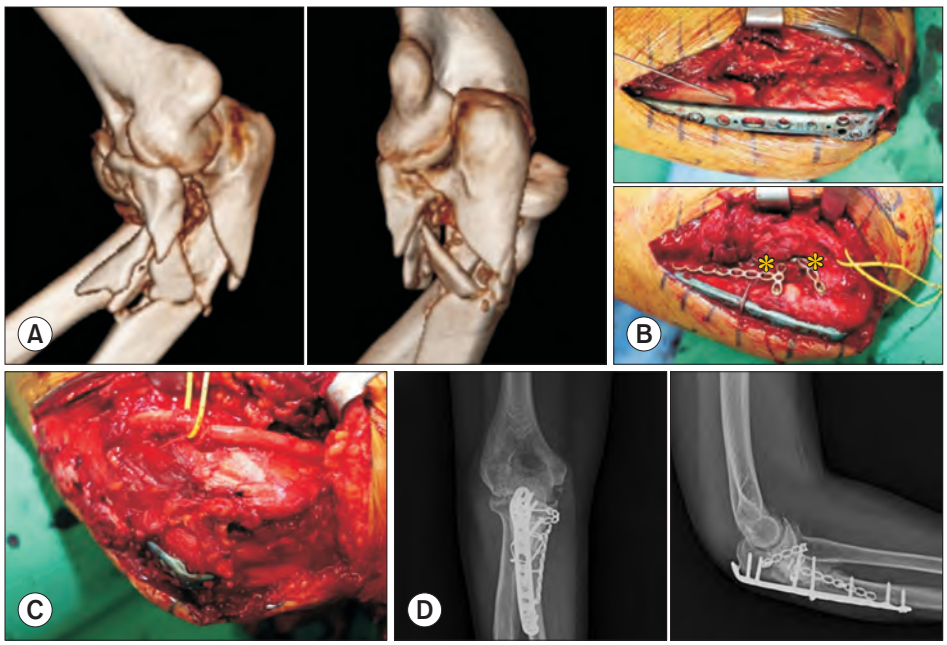

Fig. 4. A 64-year-old woman classified as having a type 3 trans-ulnar basal coronoid fracture-dislocation. (A) Three-dimensional computed tomography reconstruction of the type 3 trans-ulnar basal coronoid fracture-dislocation. (B) After the olecranon fracture was reduced and fixed with a plate, the Taylor–Scham approach was ultilized. The base and anteromedial facet fragment fractures were fixed with wiring and 2 miniplates (asterisks). (C) Ulnar nerve anterior transposition was performed at the last stage of surgery. (D) Postoperative anteroposterior and lateral radiographs at 6 months after surgery.

regions of bony continuity among the lateral, medial, anterior, and posterior cortical aspects of the proximal ulna, as observed on anteroposterior and lateral radiographs. The following parameters were evaluated: range of motion (ROM) of the elbow, elbow function, and presence of postoperative complications. Patients were asked to complete the Mayo Elbow Performance Score for functional evaluation. Scores higher than 90 were considered excellent; 75 to 89, good; 60 to 74, fair; and below 60, poor.[15]

RESULTS

Characteristics of the Patients

Of the 19 patients enrolled in the study, 3 had type 1 fractures, 14 had type 2 fractures, and 2 had type 3 fractures. The mean age was 48.95 ± 18.08 years (range, 19–90 years), and the mean follow-up duration was 15.05 ± 2.95 months (range, 12–24 months). The mechanisms of injury were traffic accidents (4 cases), sports injuries (3 cases), falls from a height (7 cases), and falling injuries (5 cases). Intraobserver reliability, shown by weighted kappa, for the classification of trans-ulnar basal coronoid fracture-dislocations was 0.884. Interobserver reliability shown by weighted kappa was 0.784.

Radiographic and Clinical Outcomes

All fractures had a solid osseous union, as observed during follow-up. No subluxations or dislocations were observed. The average arc of flexion and extension was 119.47° ± 20.88°, with a mean flexion of 127.37° ± 13.37° and an average flexion contracture of 7.89° ± 10.04°. The average Mayo Elbow Performance Score was 82.63 ± 12.51 points. The results were categorized as excellent in 5 patients, good in 9, and fair in 5. Tiny heterotopic ossification was radiographically evident in 2 patients, 1 of whom required additional surgery for posttraumatic stiffness. Patients who underwent surgery for posttraumatic stiffness were included in the type 3 fracture group. The mean range of the flexion–extension arc was 60°, which improved to 110° after surgery at the final follow-up. Among the patients, 2 complained of postoperative ulnar neuropathic symptoms that improved within 3 months without any treatment. Hardware removal was performed in 2 patients because of the symptomatic prominence of the olecranon plate.

DISCUSSION

To our knowledge, this study presents the first case series of patients with clearly defined trans-ulnar basal coronoid fracture-dislocations to demonstrate a surgical strategy based on the coronoid fracture pattern. Despite the relatively small number of cases in this series, our surgical method provided satisfactory clinical and radiological outcomes.

Since trans-ulnar basal coronoid fracture-dislocation has not been consistently defined separately in the literature, comparison with previous reports is difficult. Typically, these injury patterns have been included within the broader categories of Monteggia-like lesions or complex coronoid and proximal ulnar fractures.[1-3,6,7] However, all previous studies have reported that the management of

coronoid process fractures is an important aspect of treating these types of injuries. Ring et al.[16] reported that only signs of arthrosis were found in patients with malunited coronoid fractures and concluded that large coronoid fragments must be anatomically reduced in Monteggia fractures. Doornberg et al.[17] also reported unsatisfactory results related to inadequate fixation of the coronoid with subsequent arthrosis and emphasized the need for rigid fixation of the coronoid process to restore a stable trochlear notch. Fortunately, these injuries are relatively rare and most coronoid process fractures are large enough to achieve rigid fixation.[8] Cha et al.[8] reported several methods for the fixation of olecranon fractures with coronal plane fragments, including the entire coronoid process. Most coronal plane fragments of coronoid fractures had a wide, mountain-shaped base and could be fixed by concurrent fixation using a locking screw and cerclage wiring through a posterior incision.[8] Consistent with these findings, our study also noted that most of the concurrent coronoid fractures had large and wide bases, which were classified as type 2 fractures in the current study. Notably, when concurrent coronoid fractures are large and do not involve AMFs, they can be easily approached by dissection on the medial surface of the ulna and reflect the musculature or through the olecranon fracture in a straightforward fashion using the posterior approach.

However, a more direct approach to the coronoid may be required in case of fracture of AMF of the coronoid process.[18-20] AMF of the coronoid widens the ulnar articular surface to act as a secondary stabilizer to varus instability.[21,22] AMF is vulnerable to varus stress as approximately 60% of the facet is not supported by the metaphysis.[23] While the surgical approach depends on the fracture characteristics, a medial approach is usually needed for the reduction and fixation of AMF fractures because most AMF fractures have shearing-type fragments that are ideal for buttress plating.[12,20,22,24] In addition, it is challenging to apply a buttress plate on the coronoid process through a posterior approach for AMF fractures. Consequently, we used a full-thickness medial skin flap through a posterior skin incision and a direct medial approach for concurrent coronoid fractures, including AMF, which were classified as types 1 and 3 fractures in this study.

From the medial elbow, the AMF of the coronoid process can be exposed in 1 of 3 ways, which include over-the-top, flexor carpi ulnaris-split, and Taylor-Scham approaches.[25] In the current study, we used the over-the-top and Taylor–Scham approaches to direct the coronoid process. The over-the-top approach splits the FPM and raises the anterior portion. It has been previously reported that both the FCU-split and over-the-top approaches are suitable for performing buttress plate fixation for AMF fractures of the coronoid process and for improving elbow stability. However, fixation of AMF fractures using the over-the-top approach is technically easier and has a lower incidence of postoperative ulnar neuropathy.[12,23] The Taylor-Scham approach is easily extended into a standard dorsal approach to the elbow when needed. Furthermore, avoiding direct retraction of the ulnar nerve is a significant advantage over the FCU split. Although the Taylor-Scham approach is a difficult approach to access the anterior side of the medial collateral ligament,[14] a recent cadaveric study reported that this approach provides more extensive exposure of the anteromedial coronoid while avoiding cross-tensioning of the ulnar nerve.[13]

Our study has some limitations. First, the relatively low incidence of the fracture-dislocation pattern compelled us to study a small sample size. Second, there was no control group for the treatment outcomes between the classification types or treatment methods. Therefore, our results may not reflect the entire injury pattern of this fracture, and the surgical results may differ from those of other procedures. Nevertheless, we believe our study provides valuable guidelines for surgical approaches based on the pattern of coronoid process fractures. Third, the study had a relatively short follow-up period. Therefore, we could not assess the development of late complications, such as posttraumatic arthritis or implant failure. However, a 12-month follow-up is generally considered adequate to determine fracture healing, stability, ROM, and early surgical complications in fracture patterns and treatment studies. Lastly, we could not establish the relationship between fracture characteristics and collateral ligament injuries because of the small patient population. Thus, multicenter trials are required to obtain sufficient data.

In conclusion, most of the concurrent coronoid fractures in trans-ulnar basal coronoid fracture-dislocations had large and wide bases. In this cases, the coronoid fragments can be easily approached via medial fascial exposure from the posterior ulnar cortex or through olecranon fractures. However, in AMF fractures of the coronoid process, a direct medial approach is required for buttress plating. Despite the limited number of patients in this series, our surgical strategy yielded satisfactory clinical and radiological outcomes.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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