

Surgical treatment for terrible triad injury of the elbow with anteromedial coronoid fracture through a combined surgical approach

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Summary

Objective: To report the results of the surgical treatment of terrible triad injury with anteromedial coronoid fracture through a combined surgical approach.

Methods: This retrospective study evaluated data from patients who underwent surgery to repair terrible triad injuries and anteromedial coronoid fractures. Surgical treatment involved radial head repair or replacement, medial and lateral collateral ligament repair, and coronoid fracture fixation through combined approaches. Evaluations were performed using the Mayo Elbow Performance Score (MEPS) and anteroposterior and lateral radiographs of the elbow.

Results: Twenty-two patients (15 males, seven females; mean \pm SD age, 47.5 ± 11.4 years) were enrolled in this study. Fracture union and concentric reduction of both the ulnotrochlear and radiocapitellar articulations were achieved in all patients. The mean \pm SD follow-up was 31.6 ± 11.9 months. The mean \pm SD arc of flexion–extension was $110.3^\circ \pm 26.3^\circ$ and arc of forearm rotation was $139.5^\circ \pm 17.1^\circ$. The mean \pm SD MEPS was 88.1 ± 12.2 points, with results classified as excellent in eight elbows, good in ten, and fair in four. Six patients had radiographic signs of post-traumatic arthritis. Three patients required secondary surgeries.

Conclusion: Combined surgical approaches can be considered for the treatment of terrible triad injuries in association with anteromedial coronoid fractures.

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Keywords

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Introduction

Elbow dislocation with an associated radial head and coronoid fracture is a relatively rare injury, commonly referred to as a 'terrible triad' injury.¹ Most terrible triad injuries are managed surgically, and good results are achievable using a standard treatment protocol that includes fixation of the coronoid fracture, fixation or replacement of the radial head, and repair of the lateral collateral ligament (LCL).²⁻¹⁰ Some patients who demonstrate residual instability after this repair may require additional repair of the medial collateral ligament (MCL).³ Despite this knowledge, the optimal approach and treatment strategy for coronoid fractures in terrible triad injuries remains controversial.²⁻⁹ Indeed, a range of surgical approaches has been recommended for exposing coronoid fractures; some authors suggest an extended lateral approach or posterior incision to reduce and fix the coronoid fracture from the defect of the radial head, whereas others suggest a separate anteromedial approach.⁴⁻⁹ Likewise, several surgical methods have been recommended for fixing coronoid fractures, which include the use of Kirschner (K)-wires, suture anchors, screws and plates, the suture lasso technique, or a combination of these. Arthroscopic fixation of coronoid process fractures through coronoid tunnelling and capsular plication was also recommended.^{10,11}

Coronoid fractures are often reported as tip fractures, and anteromedial coronoid fractures in terrible triad injuries have received minimal attention.^{6,12-14} However,

we have treated a series of terrible triad injuries with anteromedial coronoid fractures through a combinatorial approach. First, a lateral Kocher approach is used to fix the radial head fracture and repair the LCL. Then, an anteromedial approach is used to directly expose, anatomically reduce, and rigidly fix the coronoid fracture. Where required, the MCL was also fixed. This current study describes the findings for a retrospective case series and investigates the efficacy of the surgical treatment of terrible triad injuries of the elbow with anteromedial coronoid fracture through a combined surgical approach.

Patients and methods

Study population

This study was a retrospective review of the hospital medical databases at three university-affiliated teaching hospitals (Zhejiang University Second Affiliated Hospital, Zhejiang University First Affiliated Hospital, and Ningbo Sixth Hospital). Patients who had undergone surgery for terrible triad injuries with anteromedial coronoid fracture through a combined surgical approach by the three senior authors (G.Y.L, W.H.M and M.L.) between December 2010 and December 2015 were identified. Inclusion criteria included closed and acute terrible triad injuries of the elbow with O'Driscoll anteromedial coronoid fracture (Figure 1).¹² Exclusion criteria included open and old injuries, patients younger than 18 years, patients

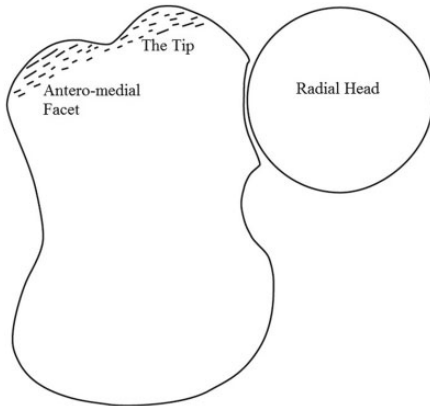


Figure 1. Schematic illustration showing a fracture of the anteromedial facet of the coronoid extending to involve the tip of the coronoid process (fracture fragment indicated by dotted lines).

with neurovascular injury, and a follow-up period of less than 24 months. Medical records and anteroposterior and lateral radiographs of the elbow were reviewed from the database to assess details of the initial injury and treatment. Patients were also invited to our hospitals for clinical and radiographic evaluation. The fractures were classified as type I, type II or type III radial head fractures according to the classification system of Mason.¹⁵ Fractures were also classified as anteromedial subtype 1, subtype 2, and subtype 3 coronoid fractures according to the system of O'Driscoll.¹²

Ethical approval was provided by the Institutional Review Board of Ningbo Sixth Hospital, Ningbo, Zhejiang Province, China (no. NPLY2017007). The patients participating in the study provided verbal informed consent.

Surgical protocol

All patients were placed in the supine position with the injured arm placed on a radiolucent table and a sterile tourniquet was applied. Combined anteromedial and lateral incisions were used. The surgical procedure included reduction and fixation

or replacement of the radial head fracture, repair of the LCL through a Kocher approach, and fixation of the coronoid fracture through an anteromedial approach. Where required, the MCL was also repaired through an anteromedial approach.

First, the radial head fracture was exposed using a Kocher approach with open reduction and screw and/or plate fixation (21 elbows). In one patient, the radial head fracture was irreparable and was replaced with a prosthesis. The LCL was usually avulsed from the supralateral condyle and was therefore temporarily sutured to provide provisional stability to the elbow joint to prevent the joint from dislocating. This was then followed by a separate anteromedial approach to directly expose the ulnar coronoid process fracture by splitting the flexor-pronator mass complex.^{5,16,17}

For small fracture fragments, the coronoid fracture was stabilized by suture anchor (one elbow), lasso technique (one elbow), or K-wires combined with suture anchors (four elbows). A combined use of K-wires and suture anchors was preferred by the surgeons. The K-wires were first used to fix the reduced fragments, and then a suture anchor was inserted to suture the anterior capsule of the fragment to protect it from displacement. For larger fracture fragments, a mini plate (four elbows), 2.7-mm cannulated screws alone (one elbow), or a combination of plates and cannulated screws (nine elbows) were used; the combination being the preferred option. The cannulated screws were first placed to hold the fracture fragments, and the plate was used to buttress and neutralize the fracture fragments. For some comminuted coronoid fractures, multiple fixation techniques combined with suture anchors, K-wires, cannulated screws or plates (in two elbows) were used. In all cases, the MCL was checked for rupture through this anteromedial approach and, where

required, the ruptured MCL was repaired with suture anchors (four elbows).

Finally, the LCL was tightened with suture anchors (18 elbows) or transosseous sutures (four elbows). The hanging arm test was used to check the stability of the elbow joint.¹⁴ Where instability persisted, the fixation and ligamentous repairs were checked and augmented where needed.

Postoperative management and evaluation

Early mobilization commenced if patients could endure the pain, usually 2 or 3 days postoperatively. Active exercises of the elbow joint were encouraged, including both flexion–extension and rotation. However, patients were advised to avoid extending the elbow beyond the terminal 20° to 30° of their normal range of motion until 4 weeks postoperatively. Prophylaxis against heterotopic ossification, such as with indomethacin or irradiation, was not routinely used.

Functional repair to the elbow joint was analysed using the Mayo Elbow Performance Score (MEPS).¹⁸ The MEPS consists of the physician's assessment of pain, ulnohumeral motion, stability, and ability to perform functional tasks. Categorical ratings are assigned as follows: 90 to 100 points is excellent; 75 to 89 points is good; 60 to 74 points is a fair outcome; and a score of less than 60 points is considered poor. Elbow range of movement was recorded in degrees. Radiographic signs of post-traumatic arthritis were recorded according to the system of Broberg and Morrey.¹⁸ The anteroposterior and lateral radiographs of the elbow were reviewed for elbow joint congruence, fracture union, the presence of heterotopic calcification, and the presence of post-fracture osteoarthritis. Where the stability of the bone union was questionable, computed tomography scans were obtained to further

evaluate the repair. The functional arc of motion was determined according to previously published criteria.¹⁹ Patients were routinely reviewed clinically and radiologically at 1, 2, 3, 6, 12, and 24 months after surgery. All patients were invited to the hospital for the final follow-up review. MEPS scores and measurements were performed by an independent observer (R.M.X.) at the final follow-up.

Statistical analyses

All statistical analyses were performed using the SPSS® statistical package, version 17.0 (SPSS Inc., Chicago, IL, USA) for Windows®. Data are presented as mean \pm SD for continuous variables. The study did not undertake any between-group comparisons using statistical tests.

Results

This retrospective review of the three medical databases identified 130 patients with 130 terrible triad injuries of the elbow treated with surgical repairs between December 2010 and December 2015. Of these, 23 (18%) patients with anteromedial coronoid fractures were identified. One patient with a follow-up period of less than 24 months was excluded, so 22 (96%) patients (15 males, seven females; mean \pm SD age, 47.5 \pm 11.4 years) with terrible triad injuries and anteromedial coronoid fractures were enrolled in this study. Surgery was performed at a mean \pm SD of 6.1 \pm 1.1 days (range, 5–11 days) after the injury. According to the classification system of Mason, there were four type I, 15 type II, and three type III radial head fractures. According to the system of O'Driscoll, there was one anteromedial subtype 1, 19 subtype 2, and two subtype 3 coronoid fractures (Figures 2, 3 and 4).

The mean \pm SD duration of follow-up was 31.6 \pm 11.9 months (range, 26–62



Figure 2. Photographs of a 46-year-old man who sustained a terrible triad injury of the elbow. Preoperative anteroposterior (AP) radiograph (A) and three-dimensional computed tomography (B) images show a Mason¹⁵ type III radial head fracture and an O'Driscoll¹² anteromedial subtype I coronoid fracture. The radial head fracture was fixed with a plate and screws, and the lateral collateral ligament was repaired by a suture anchor through a lateral approach. The anteromedial coronoid fracture was repaired with a suture anchor through an anteromedial approach. Postoperative lateral (C) and AP (D) radiographs show concentric reduction of both the ulnotrochlear and radiocapitellar articulations, with no evidence of elbow instability at the 2-year follow-up.

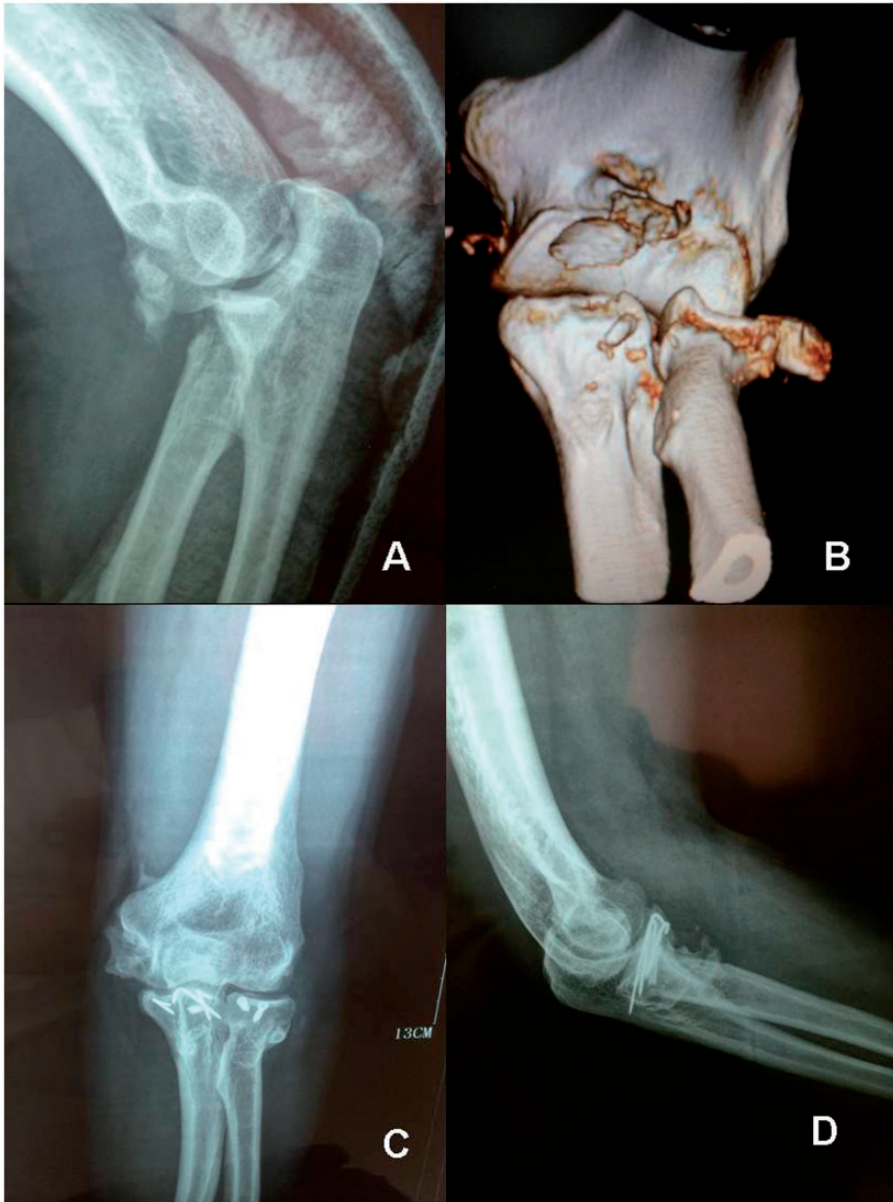


Figure 3. Photographs of a 63-year-old man who sustained a terrible triad injury of the elbow. Preoperative lateral radiograph (A) and three-dimensional computed tomography (B) images show a Mason¹⁵ type II radial head fracture and an O'Driscoll¹² anteromedial subtype 2 comminuted coronoid fracture after closed reduction of elbow dislocation. The radial head fracture was fixed with screws, and the lateral collateral ligament was repaired by transosseous sutures through a lateral approach. The anteromedial coronoid fracture was fixed with K-wires and suture anchors through an anteromedial approach. Postoperative lateral (C) and anteroposterior (D) radiographs show an elbow with bone union of fractures at the 3-year follow-up.

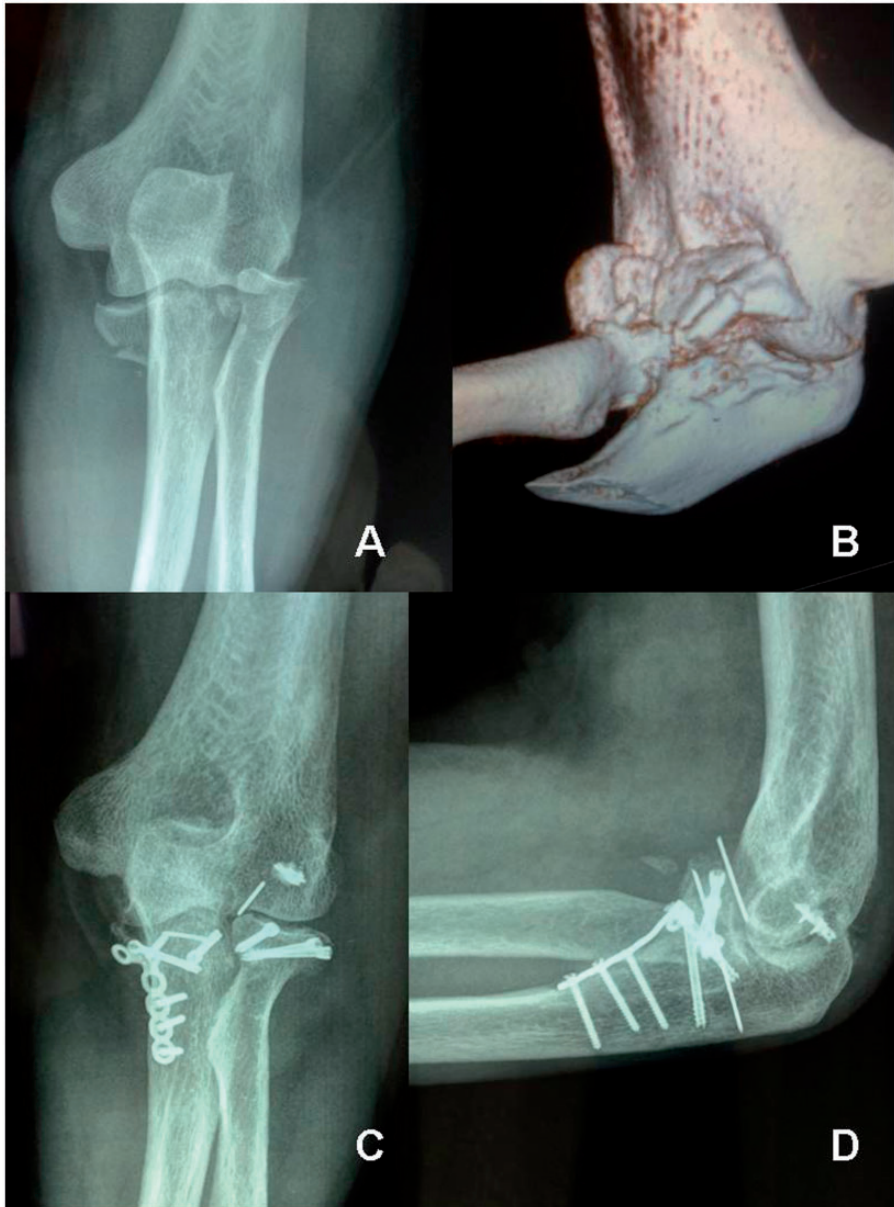


Figure 4. Photographs of a 56-year-old man who sustained a terrible triad injury of the elbow. Preoperative lateral (A) and anteroposterior (AP) (B) radiographs show a Mason¹⁵ type II radial head fracture, an O'Driscoll¹² anteromedial subtype 3 coronoid fracture, and dislocation of the elbow joint. Surgeons performed fixation of the radial head fracture and repair of the lateral collateral ligament through a lateral approach and fixation of the coronoid fracture through an anteromedial approach. Postoperative lateral (C) and AP (D) radiographs show a Kirschner wire shifting from the radial head at the 1-year follow-up, and this patient underwent a second surgery to remove the Kirschner wire.

months). The type of coronoid fracture, the treatment used and the clinical results for individual patients at final follow-up are presented in Table 1. At final follow-up, the mean \pm SD arc of flexion–extension of the elbow was $110.3^\circ \pm 26.3^\circ$, the mean \pm SD flexion contracture was $17.5^\circ \pm 14.6^\circ$, and the mean \pm SD flexion was $129.0^\circ \pm 12.4^\circ$. At final follow-up, the mean \pm SD arc of forearm rotation of the elbow was $139.5^\circ \pm 17.1^\circ$, with a mean \pm SD pronation of $70.9^\circ \pm 9.0^\circ$ and a mean \pm SD supination of $68.6^\circ \pm 10.6^\circ$. At final follow-up, the functional arc of motion was achieved in 19 of the 22 patients. At final follow-up, the mean \pm SD MEPS was 88.1 ± 12.2 points

(range, 60–100 points), which corresponded to an excellent result in eight elbows, a good result in 10, and a fair result in four. Eighteen (82%) patients returned to daily living activity. Six patients had radiographic signs of post-traumatic arthritis: four patients had grade 1 arthrosis and two patients had grade 2 arthrosis.

Patients maintained concentric reduction of the elbow joint without evidence of elbow instability. Bone union of the coronoid and radial head fractures was achieved in all patients at 3 months after surgery. Three of the 22 patients (14%) required secondary surgeries. Although four patients showed evidence of heterotopic ossification, only one patient required further surgery

Table 1. Type and treatment of coronoid fractures and clinical results in patients ($n = 22$) who experienced terrible triad injuries of the elbow.

Case	O'Driscoll anteromedial coronoid fracture	Coronoid treatment	MCL	Clinical results at final follow-up				
				Extension, °	Flexion, °	Pronation, °	Supination, °	MEPS
1	Subtype 2	PF + AS	–	30	130	60	55	70
2	Subtype 2	KW + SA	–	30	130	70	75	100
3	Subtype 2	SA	–	25	135	75	85	100
4	Subtype 2	AS	Repair	40	100	50	55	55
5	Subtype 2	LT	–	0	125	85	80	100
6	Subtype 2	PF	–	25	125	70	70	85
7	Subtype 2	PF + AS	–	15	140	75	85	95
8	Subtype 2	PF	–	30	135	75	55	95
9	Subtype 2	KW + SA	–	10	135	70	75	85
10	Subtype 2	PF	Repair	5	130	80	65	85
11	Subtype 2	PF + AS	–	10	135	55	65	70
12	Subtype 2	KW + SA	–	30	110	75	60	85
13	Subtype 3	PF + AS + KW	–	35	125	75	75	95
14	Subtype 3	PF + AS	–	20	130	75	70	85
15	Subtype 2	PF + RS + KW	Repair	0	120	65	60	95
16	Subtype 2	PF + AS	–	0	140	80	85	95
17	Subtype 2	PF	–	5	140	75	70	95
18	Subtype 2	PF + AS	–	25	135	65	60	95
19	Subtype 1	SA	–	5	135	75	80	100
20	Subtype 2	PF + AS	–	5	120	70	70	90
21	Subtype 2	KW + SA	Repair	30	130	60	55	70
22	Subtype 2	PF + AS	–	15	140	75	85	95

MCL, medial collateral ligament; MEPS, Mayo Elbow Performance Score; PF, plate fixation; AS, anteroposterior screw; KW, Kirschner wire; SA, suture anchor; LT, lasso technique; RS, retrograde screwing.

for elbow release and excision. One patient required removal of a K-wire that had shifted from the radial head at 1 year after surgery. Ulnar neurolysis and anterior transposition were also performed in only one patient. A local and superficial infection developed in one patient and it healed uneventfully after antibiotic therapy.

Discussion

In this current series of patients, most had anteromedial subtype 2 or 3 coronoid fractures (21/22 patients), which would be presumably caused, in part, by a shearing force.^{12,20,21} Indeed, a previous study used static loading experiments to apply an axial shearing force distally to cadaveric elbows and observed fracture-dislocations of the elbow joint in 19 (48%) of 40 cases.²² The final case (1/22 patients) was an anteromedial subtype 1 fracture of the coronoid and the mechanism of this fracture may have been an avulsion of the anterior capsule. An anteromedial fracture of the coronoid in a terrible triad injury is a difficult and rather rare fracture.^{12,20,21} A previous study found four cases of O'Driscoll anteromedial subtype 2 fractures of the coronoid among of group of 21 patients treated for terrible triad injuries of the elbow.⁵ Another study reported six cases of anteromedial coronoid fractures, with all cases noted to be O'Driscoll anteromedial subtype 2 fractures.²

In this current case series, 19 cases of O'Driscoll anteromedial subtype 2 fractures showed comminution that extended from the anterior to the sublime tubercle to involve the tip. This type of anteromedial fracture should be distinguished from a comminuted fracture of the tip. A tip fracture can be treated by near-anatomical reduction and nonrigid fixation, such as suture anchors or using the lasso technique, through a lateral exposure.^{3,12} However, a better approach is to reduce the anteromedial

fracture anatomically through direct medial exposure and secure the fracture rigidly with a buttress plate and screws.^{12,20,21} Any incongruity of the anteromedial facet tends to lead to instability and subluxation.^{12,23} Indeed, a biomechanical study has suggested that an anteromedial coronoid fracture fragment will affect elbow kinematics.²³ Thus, these fractures need direct exposure and anatomical reduction for proper repair. The surgeons involved in this current study preferred buttress plating or a combined fixation technique for comminuted fractures.

Several approaches have been used by others to address coronoid fractures in terrible triad injuries,^{13–15,24–26} and a consensus has yet to be reached as to which method provides the best results. Either a posterior global incision or a lateral incision is most commonly used in terrible triad injuries.^{3,4} Two previous studies recommended the use of a separate anteromedial incision for fixation of both the tip and anteromedial fractures of the coronoid process in terrible triad of the elbow, and reported excellent outcomes.^{5,8} In the present series, an anteromedial approach was used to expose the coronoid by splitting in the flexor-pronator mass.^{5,16,17} All of the patients in this current series maintained concentric reduction of the elbow joint and showed no evidence of elbow instability at the 2-year follow-up.

In this current series, the anterior bundles of the MCL were ruptured and avulsed either from its epicondylar or coronoid attachments in four patients, so suture anchors were used to repair the avulsed MCL. The coronoid fractures in these four cases were all anteromedial subtype 2 fractures. In patients with anteromedial subtype 3 coronoid fractures, the anterior bundles of the MCL were intact and attached to the fracture fragment of the sublime tubercle. This fragment should be reduced and fixed carefully, and the

anterior bundle of the MCL should be protected from iatrogenic injury.²⁷

Although anteromedial coronoid fractures are rarely reported in terrible triad injuries, it is important to apply a standardized approach and treatment for such cases. The results of this current modified surgical protocol showed good outcomes for the 22 patients in this current study. There are several major differences in the protocol presented here versus that of the standard protocol for the treatment of terrible triad injuries:³ (i) the surgeons used a separate anteromedial approach instead of a posterior incision or an extended lateral approach, as an anteromedial approach provides sufficient exposure and the chance for proper fixation of the anteromedial coronoid fracture in terrible triad injuries; (ii) the surgeons preferred the use of buttress plating or combined fixation techniques to lasso-type sutures or lag screws for anteromedial coronoid fractures, because these techniques provide rigid stability; and (iii) the surgeons checked and repaired the MCL after coronoid fixation through the same incision.

Functional results from the present study show that a mean flexion–extension arc of 110° and a supination–pronation arc of 139° could be achieved, and the MEPS was 88 points at final follow-up. The functional outcomes of this current series were similar to the findings reported in previous studies, with a mean flexion–extension arc of 100° to 127°, a mean supination–pronation arc of 126° to 156°, and a mean MEPS of 81 to 96 points.^{2–8,27–32} However, the rate of secondary surgery was lower in this current series than that reported by others, with only three patients requiring secondary procedures in this series.^{2–8,27–32}

This current study had several limitations. First, it included a small number of patients. Secondly, it was of a retrospective design with only middle-term follow-up. Prospective comparisons between different

surgical methods would strengthen the findings of this study. Future research should focus on exploring the mechanism of an anteromedial fracture of the coronoid in terrible triad injuries.

In conclusion, in this current series, most anteromedial coronoid fractures in terrible triad injuries were O’Driscoll anteromedial subtype 2 fractures. Combined surgical approaches can be considered for the treatment of terrible triad injuries of the elbow in association with anteromedial coronoid fractures.

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Declaration of conflicting interests

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