ORIGINAL PAPER
PŮVODNÍ PRÁCE

Use of Mother-Child Screws in the Treatment of Coronoid Fractures in Terrible Triad Injury of the Elbow

Použití „mother-child“ šroubů v léčení zlomenin processus coronoideus u něšťastné triády loketního kloubu

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ABSTRACT

PURPOSE OF THE STUDY

This study aims to analyze the clinical and radiographic outcomes of a consecutive series of 18 patients with terrible triad injury. The coronoid fractures of these patients were repaired using Mother-Child screw (MCS).

MATERIAL AND METHODS

Twelve men and six women (mean age: 47.2 years) with terrible triad injury of the elbow were followed up for a mean of 17.6 months (range: 13–42 months). Surgical treatment consisted of open reduction and internal fixation of coronoid fractures with MCS, radial head fracture with MCS (Mason type II, n = 10), or mini-plate (Mason type III, n = 3). Furthermore, all underwent lateral collateral ligament repair (n = 9, 100%), and in cases of persistent instability, medial collateral ligament repair was performed (n = 3, 33%).

RESULTS

At last follow-up, average arc of ulnohumeral motion was 130° (range: 65° to 150°), average arc of forearm rotation was 148° (range: 100°–160°), mean Disabilities of the Arm, Shoulder and Hand (DASH) score was 7.1 (range: 0–28.5), and mean Mayo Elbow Performance Score (MEPS) was 92 (range: 70–100). According to the Mayo Elbow Performance Index (MEPI), 10 patients were excellent in, seven patients were good, and one patient was fair. All patients had a stable elbow. No secondary coronoid fragment dislocation or implant failures was reported. Fracture healing was observed in all patients.

CONCLUSIONS

This study shows that coronoid fracture treatment with MCS may be a new, effective and easy therapeutic option in terrible triad injury.

Key words: terrible triad of the elbow, coronoid process, radial head, functional outcome.

INTRODUCTION

Elbow dislocation with associated radial head and coronoid process fractures was named by Hotchkiss as terrible triad injury due to poor outcomes (9). Ring *et al.* (23) and Kälicke *et al.* (11) reported that the rates of unsatisfactory outcome were over 60% and over 50%, respectively, in terrible triad injuries. Recognizing that the coronoid process is the primary constraint of the elbow has led to greater attention to the treatment of difficult fractures (5, 7, 24). Some authors have suggested that any associated coronoid fracture that influences the stability of the elbow should be fixed (7, 18). Various techniques have been described for the osteosynthesis of coronoid fractures, including plates, lag screws, suture anchors, or suture lasso techniques (4, 7, 13, 27). However, coronoid fracture fragments are frequently small, and makes reliable internal fixation difficult (12, 18, 25). The best surgical protocol to treat coronoid fractures in terrible triad injuries remains unclear.

This study enrolled 18 patients with terrible triad injuries, and the outcome of a modified protocol for the treatment of coronoid fragments using MCS was explored (Fig. 1), which consists of two parts of child-screws (Fig. 1, arrow A) and the mother-screw (Fig. 1, arrow C).

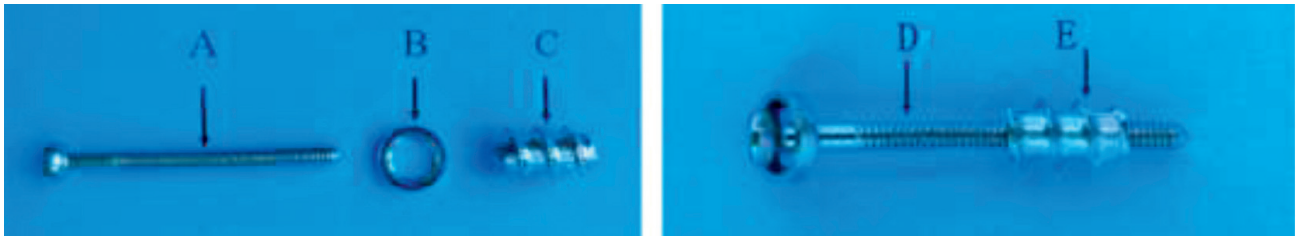

Fig. 1. Mother-child screw (MCS), which consists of two parts of child-screw (arrow A) and mother-screw (arrow C). The gasket (arrow B) is used seldom except for comminuted fractures. Child-screw, which thread as cortex screw (arrow D), has small diameter (1.5 mm) . Mother-screw is hollow design, which has external thread as cancellous lag screw (arrow E, 3.5 mm or 4.5 mm outside diameter) and inside thread (1.5 mm inside diameter). Child-screw, which thread mach the inside thread of Mother-screw, can be screwed into Mother-screw and combine with each other.

MATERIAL AND METHODS

Subjects

Between 2010 and 2014, 18 consecutive patients (12 males and 6 females; mean age: 47.2 years, range: 18 to 72 years) with terrible triad injuries were enrolled into this study. Radiographic examination of the elbow consisted of anteroposterior and lateral views. Three-dimensional (3D) reconstruction scan of the elbow was performed to reveal the degree of comminution and displacement of the fragments.

The mechanisms of injury included 15 cases of falls (11 cases from standing height and four cases from a great height), two cases of motor-vehicle accidents, and one case of bicycle accident. The fractures of the radial head were graded according to the Mason classification system, in which there were five type-I fractures, 10 type-II fractures, and three type-III fractures (14). Furthermore, fractures of the coronoid process were rated type-II in 16 patients and type III in two patients according to the Regan and Morrey classification (20). Eight patients exhibited concomitant injuries. Among these patients, six patients suffered injuries to the same extremity (one ulnar shaft fracture, one lateral humeral condyle fracture, one olecranon fracture, and three distal radial fractures), and two patients suffered concomitant injuries to other extremities (one fractures of bilateral femur and one calcaneus fracture).

All the coronoid fractures (n = 18, 100%) were fixed successfully with the MCS alone. Type-I radial head fractures (n = 5) were conservatively treated, type-II (n = 10) and type-III (n = 3) radial head fractures were fixed with MCS and a mini-plate, respectively. Associated fractures including lateral humeral condyle fracture (n = 1), ulnar shaft fracture (n = 1), olecranon fracture (n = 1) and distal radial fractures (n = 3) were fixed with plates, respectively. Furthermore, calcaneus fracture was treated conservatively, and bilateral femoral fractures were fixed with intramedullary nailings.

Mean time from injury to surgery was 7.4 days (range: 5–18 days). Medical records were reviewed for preoperative, intraoperative and postoperative information. Functional outcomes were evaluated using the Mayo Elbow Performance Score (MEPS) (15) and Disabilities of the Arm, Shoulder and Hand (DASH) score (10).

Anteroposterior and lateral radiographs were performed to detect the presence of coronoid nonunion or malunion, heterotopic ossifications, instability and posttraumatic osteoarthritis. Furthermore, degenerative changes and heterotopic ossifications were classified using the Broberg and Morrey system (2) and the classification of Hastings and Graham (8), respectively.

Treatment strategy

Patients were placed in the supine position under general anesthesia. The arms were positioned on a radiolucent hand table, and a tourniquet is applied to improve visualization.

For radial head fractures, conservative treatment was performed for type-I fractures (n = 5), open reduction and internal fixation (ORIF) was performed for type-II fractures (n = 10) with MCS, and type-III fractures were treated with a mini-plate (n = 2) and cannulated screws (n = 1), respectively, through the Kocher approach. No one needed to excise the radial head.

Next, a gentle reduction of the elbow was attempted with the elbow slightly flexed (approximately 30°). We preferred to use an anterior approach for coronoid fractures. An "S" type incision is made along the anterior aspect of the elbow, extending distally just medial to the midline of the forearm over the ulna. The biceps tendon was laterally retracted, and the *pronator teres*, median nerve and brachial artery are medially retracted. The brachial muscle was longitudinally split to expose the area of the coronoid fracture. The coronoid fragments were reduced to the anatomic position using small forceps.

One K-wire (1.5 mm) was selected as a guide pin to drill a pilot hole from the coronoid fragment to the fracture bed of the ulna (Fig. 2a). After moving aside the fragments to expose the pilot hole of the fracture bed, the mother screw was inserted into the fracture bed over the guide pin (Fig. 2b) and was buried below the fracture surface at approximately 2–3 mm. Under direct visualization, the child screw was placed into the pilot hole of the coronoid fragment (Fig. 2c). Then, the child screw was placed into mother screw and was screwed

tightly to compress the fracture (Fig. 2d). Generally, one fragment was fixed with one MCS. If there were comminuted coronoid fractures and more than one fragment needed to be fixed, the same technique was repeated. No supplemental fixation was needed in all these cases (Figs. 3 and 4).

After fixation of the bone fractures, the lateral collateral ligament injury (LCL; n = 9, 100%) was repaired with suture anchors or transosseous sutures. Then, the hanging arm test was performed to assess the stability of the elbow (7). If the elbow was still unstable, the medial collateral ligament (MCL; n = 3, 33%) would be repaired using the same techniques.

The wound was closed in layers with absorbable sutures. After anteroposterior and lateral radiographs were performed to ensure the appropriate stability of the elbow, a sling was applied for four weeks. During this period, active and passive elbow exercises (flexion, extension, pronation and supination) were gradually initiated under the supervision of a physical therapist. Indomethacin or irradiation was not used as a prophylaxis against heterotrophic ossification.

Evaluation

All patients were followed up clinically and radiographically for a mean of 17.6 months (range: 13–42 months). A clinical evaluation was performed every week in the first two months, every four weeks in the subsequent three months, and every three months thereafter. Functional outcomes were evaluated using MEPS and DASH scores. Anteroposterior and lateral radiographs were performed to detect the presence of coronoid nonunion or malunion, heterotopic ossifications, instability and posttraumatic osteoarthritis. Radiographic signs of post-traumatic arthritis were rated according to the criteria of Broberg and Morreysystem (2). Heterotopic ossifications were classified using the functional classification of Hastings and Graham (8).

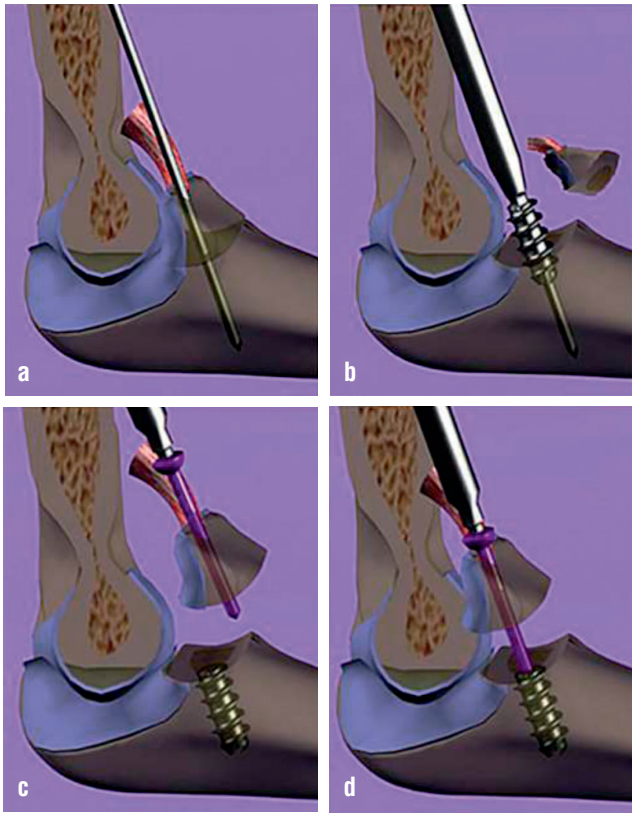

Fig. 2a–d. Illustration depicting the new technique of coronoid fixation using MCS. A – the K-wire (1.5 mm) was choiced as guid pin and drill a pilot hole from the fragments of coronoid process to proximal ulna; b – after moving aside fragments generally and exposing the pilot hole of fracture bed of ulna, mother-screw can be inserted into the fracture bed over the guide pin and be buried below the fracture surface about 2–3mm; c – under direct visualization, Child screw was put into the pilot hole of the fragment; d – child screw was placed into Mother-screw and screwed tightly each other to reach compress of fractures.

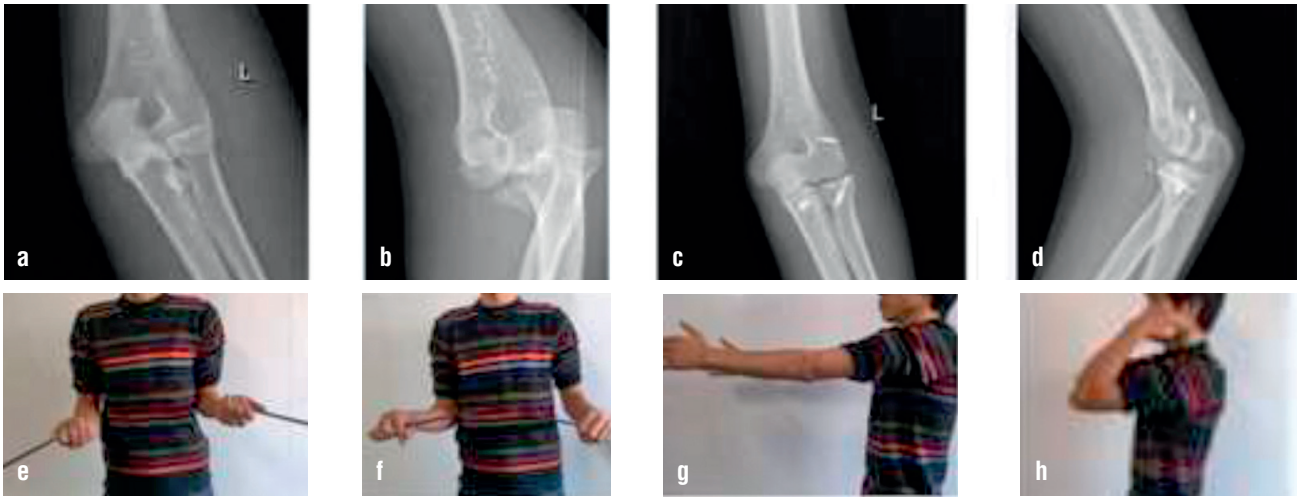

Fig. 3. A 22-year-old man with a left terrible triad injury and injuries of LCL and MCL. Preoperative anteroposterior (a) and lateral (b) radiographs demonstrating a Regan-Morrey type II coronoid fracture and a Mason type II fracture. Postoperative anteroposterior (c) and lateral (d) demonstrating fixation of the coronoid fracture and radial head fracture with 1 MCS respectively and repaired LCL with suture anchor. Elbow range of motions at follow-up (e–h).

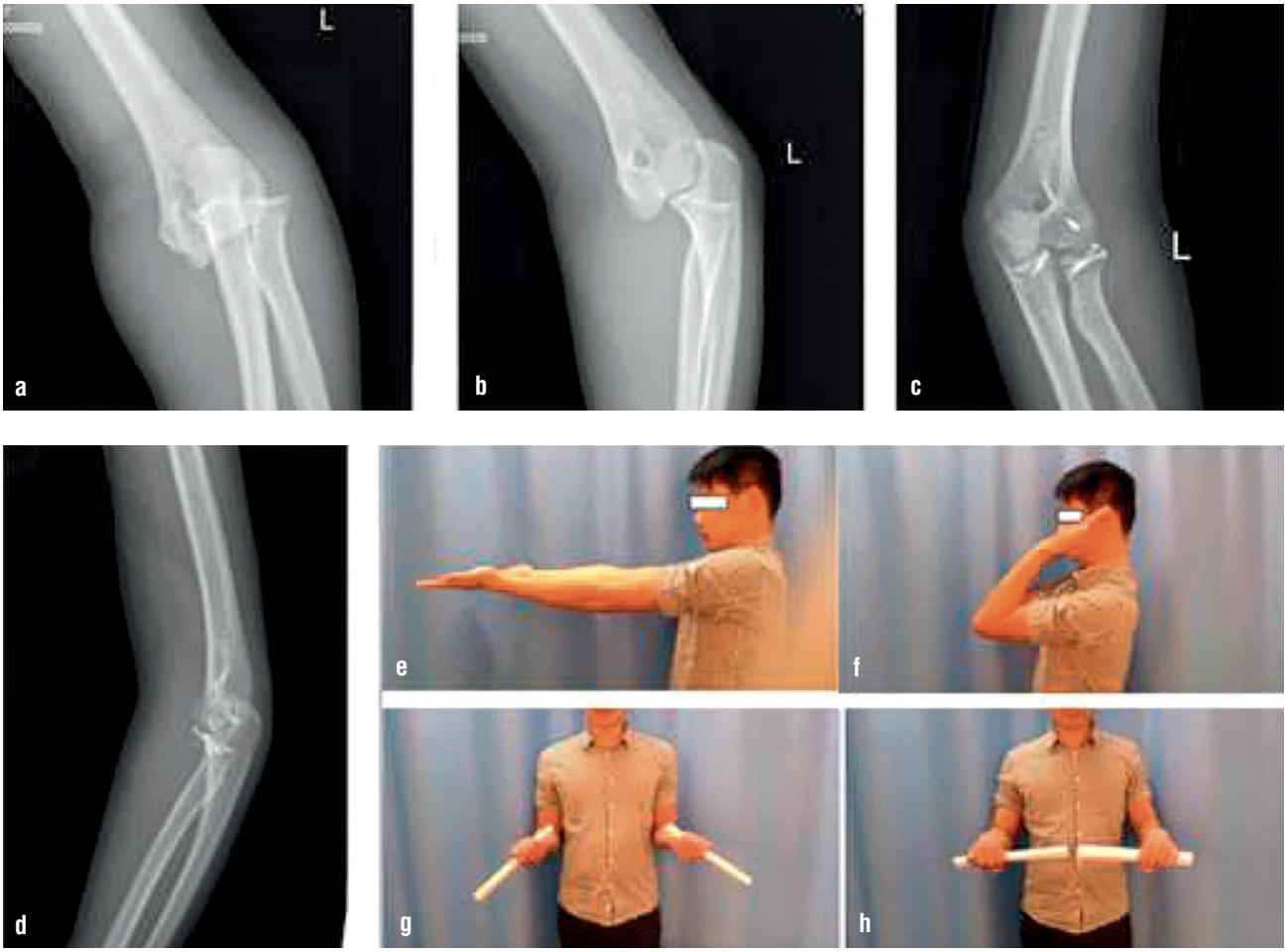

Fig. 4. A 31-year-old man with a terrible triad injury and MCL injury of the right elbow . Preoperative anteroposterior (a) and lateral (b) radiographs demonstrating a comminuted type II coronoid fractures and a comminuted type II radial head fractures. Postoperative anteroposterior (c) and lateral (d) radiographs demonstrating fixation of the coronoid fractures and radial head fractures with 2 MCSs respectively. Elbow range of motions at follow-up (e–h).

RESULTS

The patients' characteristics, fracture classifications, treatment and clinical results are shown in Tables 1 and 2.

At the last follow-up, the average arc of ulnohumeral motion was 130° (range: 65° to 150°), with an average extension of 7° (range: 0°–35°) and flexion of 137° (range: 100°–150°). The average arc of forearm rotation was 148° (range: 100°–160°), with an average pronation of 79° (range: 55°–90°) and an average supination of 69° (range: 45°–75°). Furthermore, mean DASH was 7.1 (range: 0–28.5) and the mean MEPS score was 92 (range: 70–100). According to MEPI, results were excellent in 10 patients, good in seven patients, and fair in one patient.

Radiological evaluation revealed that the coronoid and radial head fractures healed in all patients within the first five months. All patients maintained a concentric reduction in both ulnotrochlear and radiocapitellar articulation at the last follow-up. No secondary coronoid fragment dislocation or implant failures were observed, and no one required additional surgery.

According to the Broberg and Morrey system, osteoarthritis occurred in two patients, and was rated as grade-I and grade-III, respectively. Heterotopic ossifications were observed in five patients, but no one required reoperation.

The patient with a fair result had grade-III osteoarthritis and heterotopic ossification. However, this patient did not undergo reoperation due to poor compliance and general clinical condition.

DISCUSSION

Several anatomical, biomechanical and clinical studies have demonstrated the important role played by the coronoid process in elbow stability against axial, posterolateral rotator, or varus loads (5, 19, 22, 24)**.** The majority of the coronoid fractures in terrible triad injuries were small, involved <50% of the coronoid height, and were frequently comminuted (1, 6). Since small fracture fragments could not be effectively fixed and often led to fragment breaks, ORIF of the coronoid fracture remains a challenge for orthopedic surgeons (12, 18, 25).

Table 1. Summary of patient characteristics

Case Number	Sex	Age (years)	Ligament injury	Mechanisms of injury	Regan-morre y type	Mason type	Days betveen injury and surgery	Associated injury
1	F	70	LCL	Fall (SH)	II	III	9	Ipsilateral ulnar shaft fractures
2	M	18	–	Fall (SH)	II	I	5	–
3	F	71	LCL, MCL	Fall (SH)	II	III	7	Ipsilateral olecranon fracture
4	M	59	LCL	Fall (SH)	II	I	5	Ipsilateral distal radius fracture
5	M	22	LCL, MCL	Fall (GH)	II	II	18	Bilateral femoral shaft fractures
6	M	42	MCL	Fall (SH)	II	II	6	–
7	M	38	LCL	Fall (GH)	II	II	5	Ipsilateral distal radius fracture
8	M	58	–	Fall (SH)	II	I	8	–
9	F	67	MCL	Fall (SH)	II	II	7	–
10	M	31	MCL	Fall (GH)	II	II	11	–
11	M	39	LCL, MCL	Motor vehicle accident	II	III	6	–
12	M	30	MCL	Fall (SH)	II	II	7	–
13	F	72	–	Fall (SH)	III	I	6	–
14	M	32	–	Fall (SH)	III	II	5	–
15	M	26	LCL, MCL	Fall (GH)	II	II	7	Calcaneal fracture
16	M	50	LCL	Motor vehicle accident	II	I	9	Ipsilateral lateral humeral condyle fracture
17	F	65	LCL, MCL	Bicycle accident	II	II	5	–
18	F	59	–	Fall	II	II	8	Ipsilateral distal radius fracture

MCL – medial collateral ligament; LCL – lateral collateral ligament; SH – standing height; GH – greater height

Various techniques have been described to treat coronoid fractures, including techniques that use transosseous sutures, K-wires, screws and mini-plates (4, 7, 13, 27). ORIF with screws were indicated in larger coronoid fragments (4, 21). Mini-plates have been used in coronoid fractures, but often required a wide exposure and ulnar nerve release, which increased surgical complexity and operative time (4, 13). With the use of suture anchors or suture lasso alone for the treatment of type I-II coronoid fractures, a period of partial or total immobilization is frequently needed to avoid secondary fragment mobilization; and elbow contractures are often observed in these cases (18, 26). Several techniques of coronoid reconstruction have been described using radial head fragments or the iliac crest bone. However, the outcomes were not consistent (12, 17, 25).

Garrigues *et al.* (7) concluded that the coronoid piece is often small, and that drilling, reducing and obtaining effective screw fixation can be challenging. Furthermore, failure of the coronoid fixation was significantly more common with screw fixation. In addition, if fragmentation occurs, further fixation becomes more difficult. Hence, use of the suture lasso technique was recommended for coronoid fixation. Ring *et al.* (23) also noted that smaller coronoid fragments were more troublesome with regard to elbow instability. Hence, fixation with a suture lasso or a suture lasso supplemented with a screw for larger fragments was also recommended.

In our patients, all coronoid fractures (comminuted or not) were treated successfully with just 1–3 MCSs. Intraoperation was performed, because only the child screw (diameter: 1.5 mm) should be inserted through

Table 2. Summary of patient outcomes

Case Number	fixation		Ligament	Rang of motion		MEPS	Post-operative complications	DASH	MEPI
	Coronoid /NO.	Radial head /NO.		Extension / Flexion (°)	Pronation / Supination (°)				
1	MCS/1	Plate /1	LCL (repair)	15/135	75/65	85	HO	18.4	Good
2	MCS/1	CT	–	0/140	80/75	100	–	2.5	Excellent
3	MCS/1	cannulated screws/2	LCL (repair) MCL(repair)	35/100	55/45	65	HO, PA	28.5	Fair
4	MCS/2	CT	LCL (repair)	5/140	85/75	90	–	5.2	Excellent
5	MCS/1	MCS/1	LCL (repair) MCL (CT)	5/145	85/75	100	–	0	Excellent
6	MCS/1	MCS/2	MCL (CT)	0/140	90/70	100	–	4.3	Excellent
7	MCS/1	MCS/1	LCL (repair)	10/135	70/55	85	–	14.8	Good
8	MCS/3	CT	-	0/140	80/75	100	–	0	Excellent
9	MCS/1	MCS/1	MCL(CT)	10/140	85/65	95	HO	5.7	Excellent
10	MCS/2	MCS/2	MCL(CT)	0/145	80/75	100	–	0	Excellent
11	MCS/1	Plate/1	LCL (repair) MCL (repair)	10/135	65/55	80	–	15.1	Good
12	MCS/1	MCS/2	MCL (CT)	5/145	85/75	100	–	0	Excellent
13	MCS/2	CT	-	5/130	85/65	95	–	5.7	Excellent
14	MCS/2	MCS/1	LCL (repair)	5/140	85/75	95	–	3.1	Excellent
15	MCS(1)	MCS/2	LCL (repair) MCL(CT)	0/150	85/65	100	–	2.3	Excellent
16	MCS/2	CT	LCL (repair)	10/125	70/65	85	HO	11.6	Good
17	MCS(2)	MCS/2	LCL(repair) MCL (repair)	10/135	85/75	95	HO, PA	4.6	Excellent
18	MCS/2	MCS/1	LCL (repair) MCL (CT)	5/140	85/75	90	–	6.2	Excellent

MCS – mother-child screw; MCL – medial collateral ligament; LCL – lateral collateral ligament; CT – Conservative treatment; HO – heterotopic ossification; PA – post-traumatic arthritis; MEPS – Mayo Elbow Performance Score; (90,75-89,60-74,59) DASH – Disabilities of the Arm, shoulder, and Hand score.

the fragment, in order to effectively avoid coronoid fragment breaks. Furthermore, MCS can address even the small coronoid fragments in conditions where conventional implants seem too bulky. In this study, no coronoide fragments shattered and no auxiliary fixation was needed. Furthermore, no secondary fragment dislocation or implant failures were observed. Radiological evaluation revealed fracture healing in all patients within five months.

Achieving a stable reduction of the elbow allows early mobilization, which is important in treating terrible triad injuries (16, 18). Garrigues *et al.* (7) observed 29% instability in the group with suture anchor fixation of the coronoid fracture, and 20% instability in the group with screw fixation; although there was no instability in patients that underwent the suture lasso technique. In a multicenter series and with a mean follow-up of 34 months, Pugh *et al.* (18) reported that 15 patients were rated as excellent, 13 patients were rated as good, seven patients were rated as fair, and one patients were rated as poor by MEPS. It was concluded that these outcomes were directly related to the period of immobilization, and that patients who had prolonged immobilization did not do as well. Kälicke *et al.* (11) also reported that six patients (6/27, 22.2%) sustained recurrent dislocations or subluxations of the elbow joint with terrible triad injuries, and that these patients with prolonged immobilization have been shown to generally have poor results, compared with those with early activity. Broberg and Morrey (3) noted that immobilization for more than four weeks consistently led to poor results.

In our cases, the initial or late instability of the elbow was not observed. Patients only wore a sling for three weeks, and elbow exercise began on the first day postoperative. Furthermore, no stiffness and no dislocation of the elbow were encountered. According to the MEPI, the rate of excellent and good results was 94% (17/18). The author believes that the achievement of the stability of the elbow was related to the mother screw. The mother screw (diameter: 3.5 mm), which has the same thread as cancellous screw (Fig. 1, arrow E), has a strong anti-pull force. During intraoperation, the mother screw was initially inserted into the cancellous bone of the fracture bed. Then, the child screw with the fragment was screwed into the mother screw and was gradually tightened to achieve fracture pressure. Hence, rigid fixation of the coronoid fragment with MCS and early mobilization of the elbow were possible.

The current study shows that the treatment of coronoid fractures with mother child screws may be a new, effective and easy therapeutic option in terrible triad injuries. Furthermore, MCS can more easily be performed and provide a more stable fixation that does not require the application of an external fixator. The authors believe that the technique of the stable fixation of the coronoid fracture with MCS and early mobilization of the elbow

are keys to these good results. However, this study has some limitations. First, the absence of a control group prevented the comparison of results obtained using MCS with those obtained using plates, sutures, or screws. The second limitation is the relatively small number of cases examined.

Indication

• Regan-Morrey type II or III coronoid fracture of the ulna with or without associated elbow dislocation.

• Comminuted fractures of the coronoid were not fixed using the conventional method.

Contraindications

• The proximal ulna was a comminuted fracture, and there was not enough cancellous bone for the mother screw.

Pitfalls

• Maintain the anatomic reduction of the fragments during placement of the guide pin, in order to prevent malreduction or fixation failure.

• In intraoperative fluoroscopy, enough space should be reserved between guide pins, on order to avoid collision with each other in the mother screws.

• Under fluoroscopy, ensure that the child screw is screwed into mother screw.

CONCLUSIONS

This study shows that coronoid fracture treatment with MCS may be a new, effective and easy therapeutic option in terrible triad injury.

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