Dual Plate Fixation of Mason Type III and IV Radial Neck Fractures: a Mid-term Follow-up of 9 Cases

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Research article

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Abstract

Background: Radial head and neck fractures commonly occur in elbow injuries. The purpose of the present study was to evaluate the effectiveness of the dual plate fixation technique for fractures of the radial neck.

Methods: This prospective study included 9 patients who were referred to our department by trauma surgeons between July 2014 and March 2018. 8 patients had a Mason type III fracture, and 1 patient had a Mason type IV fracture. The functional outcomes of dual plate fixation were evaluated via the range of motion (ROM) of the elbow joint, Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, Mayo Elbow Performance Index (MEPI), and the Broberg and Morrey Index. Radiographic images were also reviewed during follow-up.

Results: After a mean follow-up period of 50 months (24–69), the mean elbow flexion was 134°, extension was 5°, pronation was 76°, and the mean supination was 78°. The mean DASH score was 6.3. The mean MEPI was 97, and the mean Broberg and Morrey Index was 97. At the time of the last follow-up, the average humeroradial joint space was 2.5 mm, and the average inclination of the radial head relative to the neck was 2.2°. There were no incidences of wound infection, delayed union, nonunion of the fracture, or secondary displacement.

Conclusions: Mason type III–IV radial neck fractures can be fixed using the dual plate technique with sufficient midterm results for both fractures that involve the radial head and those that do not.

Trial registration: 2020-KY-096(K)

Background

Isolated radial neck fractures and those associated with fractures of the radial head are common in elbow injuries [1]. However, the treatment of such fractures is still in dispute. Recommended management techniques, including radial head excision [2,3], radial head arthroplasty (RHA) [4,5,6], and open reduction and internal fixation (ORIF) with screws or plates [7–9] have been reported with various outcomes, and the optimal technique remains controversial [10–13].

Radial head excision is the least technically challenging method for the treatment of a radial neck fracture. However, complications, such as longitudinal migration of the radius, subluxation of the inferior radio-ulnar joint, and instability of the elbow limit its applications [2,3]. Radial head arthroplasty (RHA) has been reported to be a valid treatment method, leading to favorable mid-term outcomes; however, this method yields relatively poor long-term results [4,5]. The rate of revision after RHA has been reported to be as high as 38.9% due to the complications of painful loosening, humeroradial collision, and joint instability[6]. Thus, some authors prefer open reduction and internal fixation with screws or plates[10,12,13].

The purpose of this study is to determine the outcomes of the dual plating technique to treat Mason type III–IV radial neck fractures with or without radial head involvement.

Methods

Subjects

This prospective study included patients who were referred by one of the authors (AN, ZQ) from July 2014 to March 2018 and presented with Mason III-IV radial neck fractures with or without radial head fractures. All patients underwent surgery using the dual plate technique. Informed consent was obtained from the patients involved in the study, and ethical approval was granted from the internal review board at our institution. This study was conducted according to the principles of the Declaration of Helsinki.

Patients with acute radial neck fractures, with or without a radial head fracture, and without significant osteoporosis were included in this study. The exclusion criteria were open fractures, pathological fractures, fractures for which treatment was delayed for more than 2 weeks, and patients with a history of ipsilateral elbow injuries leading to poor function.

A total of 9 patients met the inclusion criteria (male:female = 2:7). The mean patient age was 46 years (15–66). The study included 4 left elbows and 5 right elbows. 7 patients were injured during a fall from standing height (low energy injury) and 2 patients were injured in motor vehicle accidents. The average time from injury to surgery was 3 days (1–4). There were 5 Mason IIIa fractures, 3 Mason IIIb fractures, and 1 Mason IV fracture categorized according to the Mason/Johnston classification[2]. All 5 radial head fractures were complex 3-part fractures with fracture lines involving the radial neck. Posterior dislocation of the elbow was identified in 1 case, and a concomitant coronoid fracture (O'Driscoll type I) was found in 2 cases (Table 1).

Table 1
Overview of Demographics

ID	Sex	Age(years)[a]	Side	Injury mechanism	Type[b]	Complete isolation of head from neck	Associated injury
1	F	57	L	Falling	IV	Yes	Dislocation of the elbow;
2	F	50	L	Falling	IIIb	Yes	None
3	F	66	R	Falling	IIIa	Yes	Ulnar coronoid fracture
4	F	38	R	Falling	IIIa	Yes	None
5	M	56	R	Falling	IIIa	No	None
6	F	52	L	Motor vehicle collision	IIIa	No	Ulnar coronoid fracture
7	F	32	R	Falling	IIIb	Yes	None
8	M	46	R	Motor vehicle collision	IIIa	Yes	None
9	F	15	L	Falling	IIIb	Yes	None
a: at the time of trauma							
b: associated radial head and neck fractures according to the Mason/Johnston classification							
M = Male; F = Female; L = Left; R = Right							

Operative technique

The patient was placed in the supine position and administered general anesthesia. The affected extremity was placed at 90° abduction and positioned on a radiolucent hand table with a tourniquet on the upper arm. A standard Kocher's incision was performed, which started from the lateral epicondyle and continued distally for 6 cm along the radial shaft. After dissection of the skin and subcutaneous tissue, a T-shaped incision was made to the extensor digitorum communis. Then, the annular ligament was incised to expose the radial head and neck, as well as the proximal radius 5 cm distal to the head.

The hematoma in the joint was removed, and all bone fragments were identified. The articular segments of the head were reduced to ensure that the proximal and upper radioulnar articular surfaces were smooth. These segments were stabilized using 0.8–1.0 mm K-wires. The wires were directed from the safe zone to the articular surface of the proximal radioulnar joint without protruding into the joint. The reduced radial head was then reduced to the neck-shaft segment temporarily with K-wires. The reduction was then checked using anteroposterior and lateral radiographs via a C-arm X-ray machine. A contoured 2.0 mm T-plate (with 4 holes at the distal end) was used to fix the fractures. The proximal end of the plate was positioned on the safe zone of the proximal radius and the distal end was attached to the radial shaft. 2 or 3 screws were inserted into the proximal holes parallel to the articular surface, and 3 screws were used in the distal holes of the plate (Fig. 1-A, C, D).

Then, the forearm was pronated and the reduction of the proximal radius corresponding to the proximal radioulnar joint was assessed with any necessary adjustments applied in order to achieve a satisfactory reduction. A 2.0 mm straight plate with 4 holes or a 2.0mm T-plate (with 2 holes at proximal end, 4 holes at distal end) was used to strengthen the fixation. This plate was placed longitudinally on the medial side of the proximal radius. Its proximal end was positioned on the non-articular portion of the proximal radius proximal to the fracture line, and the distal end was placed on the radial shaft. Fixation was achieved with the insertion of 1 or 2 screws through the hole proximal to the fracture line and 3 screws distal to the line. The proximal hole of the plate was contoured so that the proximal screw was directed to the anterolateral articular surface (Fig. 1-B, C, E). The reduction and fixation were then checked using anteroposterior and lateral radiographs via a C-arm X-ray machine. Then, the annular ligament was repaired. The rotation of the forearm was tested passively to ensure that there were no obstructions of the upper radioulnar joint. The extensor digitorum communis and skin were closed.

In cases where the radial neck fracture was simple, anatomic reduction was performed by reviewing the morphological characteristics of the fracture, especially the fracture line of the cortical bone corresponding to the proximal radioulnar joint. However, when compression or comminution fracture patterns were identified at this site, it was difficult to reduce the radial neck only by inspecting the morphological characteristics. In these patients, the reduction of the reduced radial head to the neck was performed with the forearm in full supination while adjusting the position of the radial head so that the safe zone was in the anterolateral position and the longest articular surface of the proximal radius met the radial notch of the proximal ulna. The reduction was then maintained with K-wires, and the rotation of the forearm was assessed. The height of the head relative to the proximal ulna was restored. Radiographs obtained using the C-arm X-ray were used to check the reduction, and the joint line between the humeroradial and humeroulnar joint was made to be equal in the anteroposterior view. The final fixation was performed after normal pronation and supination at the proximal upper radioulnar joint was achieved. In 3 cases, cancelous bone grafts harvested from the lateral epicondyle of the distal humerus were used to fill defects that occurred at the radial neck. In the case of elbow dislocation, relevant ligaments were sutured using 3 bone anchors. The concomitant coronoid fractures in 2 cases were left untreated.

Postoperative management

A hinge elbow brace was applied after the operation for 4 weeks. The patient was encouraged to initiate extension and flexion of the elbow and rotation of the forearm as soon as possible. The sutures were removed at 2 weeks postoperatively. Elbow range of motion was assessed, and radiographs were obtained to assess the union of the fractures every 6 weeks for 3 months, then every 2 months thereafter.

Evaluation

We recorded the total operation times and the time required for the skin incision to heal. The humeroradial joint space and inclination of the radial head were assessed using anteroposterior and lateral radiographs obtained at the last follow-up visit. The flexion, extension, and rotation of the forearm were assessed and recorded. The elbows' functional outcomes were evaluated according to the criteria of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, Mayo Elbow Performance Index (MEPI), and Broberg and Morrey Index.

Results

The mean operation time was 74 minutes (40–95). All skin incisions healed smoothly. The mean hospital stay was 5 days (2–6). The 9 patients were followed up for an average of 50 months (24–69).

At the final evaluation, all 9 patients obtained a comparable flexion arc to the unaffected side, with a mean flexion of 134.4° (122.9–146.5). 7 patients gained an extension arc equal to the unaffected side, while 2 patients had a loss of extension of more than 10° (13° and 15°).

The mean arc of forearm rotation was 154.1° (148.9–166.5), with a mean deficit of 7.1° (1.5–11.7) compared to the unaffected side. Only 1 patient presented a larger deficit of forearm rotation (11.7°) (Table 2). The implants were removed in 2 patients at 13 and 16 months postoperatively due to personal reasons.

Table 2
Objective physical outcome measures

ID	Flexion (°)	Extension (°)	Pronation (°)	Supination (°)	Flexion-extension (°)	Supination-pronation (°)	Deficit (°) [a]
1	136.9	5.0	74.1	77.2	131.9	151.3	7.2
2	140.4	3.0	73.0	75.9	137.4	148.9	4.0
3	133.0	0.0	74.2	74.9	133.0	149.1	11.7
4	136.3	15.0	74.1	80.3	121.3	154.4	9.3
5	129.4	4.8	76.2	78.3	124.6	154.5	6.8
6	122.9	5.5	75.0	76.5	117.4	151.5	6.7
7	135.0	8.0	74.5	77.4	127.0	151.9	8.2
8	128.8	13.0	80.0	78.5	115.8	158.5	8.7
9	146.5	-5.0	83.0	83.5	151.5	166.5	1.5

a: the deficit of supination-pronation movement on the affected elbow compared to the unaffected elbow

The mean Brobery and Morrey Index was 97 (90–100); 8 cases classified as excellent results and 1 case was classified as having good results. According to the MEPI criteria, all 9 patients obtained an excellent outcome with a mean score of 97 (92–100). The mean DASH score was 6.3 (0–20.0). At the final evaluation, the average humeroradial joint space was 2.5mm (2.0–3.0), and the average inclination of the radial head relative to the radial neck was 2.2° (0.4–3.4) (Table 3). Mild heterotopic ossification was found in 2 cases.

Table 3
Postoperative outcome

ID	DASH[a]	Broberg and Morrey Index[b]	MEPI[c]	Humeroradial joint space (mm)	Inclination of the radial head (°)
1	20	90, good	92, excellent	2.4	0.4
2	0	98, excellent	99, excellent	2.7	2.2
3	7.5	97, excellent	96, excellent	2.6	2.1
4	5.8	98, excellent	98, excellent	2.4	2.7
5	2.5	97, excellent	98, excellent	2.7	1.7
6	8.3	97, excellent	97, excellent	2.6	2.8
7	5.8	98, excellent	99, excellent	2.2	3.4
8	6.7	97, excellent	95, excellent	3.0	2.8
9	0	100, excellent	100, excellent	2.0	1.8
a: Disabilities of the Arm, Shoulder, and Hand (DASH). Outcome Measure was scored on a scale ranging from 1 to 100 points. The lower the score, the better were the clinical results.					
b: Broberg and Morrey functional rating index, Score: 95–100 points: excellent, 80–94 points: good, 60–79 points: fair, < 60 points: poor.					
c: Mayo Elbow Performance Index (MEPI),19 Score: 90–100 points: excellent, 75–89 points: good, 60–74 points: fair, < 60 points: poor.					

1 patient with a Mason type IV fracture complained of weakened strength and flexibility with minor pain (Fig. 2). The DASH, Brobery and Morrey Index, and MEPI of this patient were 20, 90, and 92, respectively.

No patient experienced an infection, persistent radial nerve palsy, fracture dislocation, delayed union, or fracture nonunion.

Discussion

Although ORIF is recommended by some authors[7–9], the optimal fixation method for fractures of the radial neck remains controversial. Crossed screw fixation is technically less demanding with equal or even higher stability than the stability provided by plate fixation[11,13,14]. Clinical studies have shown that screw fixation has less of an impact on forearm rotation compared to plate fixation[10,12]. However, screw fixation is not indicated in comminuted radial head and neck fractures[9]. In addition, radial neck fractures with involvement of the radial head are often associated with axial instability, which leads to difficulties obtaining sufficient stability in the fracture using screw fixation alone [10].

Cro¨nlein et al. reported the midterm results of a low-profile locking plate used to fix 20 cases of Mason type III–IV radial head fractures. Unrestricted elbow movement was achieved in half of the patients, while a deficit of extension or rotation of 5° to 10° was observed in the remaining half[8]. A biomechanical study suggested that a rigid connection may not be established in the fracture site when fixation is achieved with a unilateral plate, which may increase the risk of failure under bending and torsional loads[13]. Clinical follow-up results showed considerable implant failure and revision rates for radial head and neck fractures that were fixed using unilateral plates, suggesting that this method achieves insufficient stability[15,16]. Another clinical study of radial neck fractures with radial head involvement was conducted by Gruszka et al. [15]. They examined 34 patients whose fractures were fixed using locking plates and reported a revision rate of 21%, with early failure of the fixation in 1 patient. Likewise, Raven et al. [16] reported a fixation failure rate of 13.6% in patients who underwent locking plate fixation.

In the present study, 9 patients with fractures of the radial neck and head were treated using a dual plating technique, and the plate was placed on the anterolateral and medial sides of the proximal radius. After a mean follow-up time of 50 months, all fractures had healed by first intention, with a mean ROM of 129°, which was equivalent to the unaffected side. Only 2 patients exhibited significant extension deficiencies of 13° and 15°. The mean forearm rotation was 154.1°, with a mean deficit of 7.1° compared to the unaffected side. Only 1 patient showed a significant forearm rotation deficiency of 11.7°. The mean MEPI, Brobery and Morrey Index, and DASH scores were 97, 97, and 6.3, and only 1 patient reported mild pain. Rigid internal fixation was achieved through dual plate fixation, with no implant failure observed in this study. Except for 2 patients for whom the implant was removed after recovery due to personal reasons, no subsequent surgeries were required. These findings are consistent with those of a study conducted by Cro¨nlein et al. [8]. However, being different from the revision rate of 21% as reported by Gruszka et al. [15], there were no cases in our study that require revision. We measured the humeroradial joint space and inclination of the radial head relative to the neck and did not find any joint space narrowing or radial head collapse. These results suggest that, unlike the eccentric fixation of the unilateral plate, dual plate fixation may provide better stability to the fracture, with lower rates of fixation failure and better curative effects. The rigid fixation by dual plating enables the patients to perform early mobilization, which might be one of the reasons for the relatively unrestricted elbow motion. In addition, none of the patients in this study experienced delayed union, nonunion, or radial head necrosis, suggesting that the probable effect of promoting fracture healing by dual lateral fixation provides sufficient stability.

Limited forearm rotation has been reported in patients who undergo plate fixation compared with those who undergo screw fixation [12]. This may be due to the excessive dissection of the soft tissues around the radial neck, which could lead to postoperative adhesions and heterotopic ossification. Contact between the plate and the proximal radioulnar joint due to mismatching may also play a role in the decreased forearm rotation observed in these patients [10,12]. Only 1 patient in our study had a forearm rotation deficiency of more than 10°, and the remaining patients obtained full forearm rotation, suggesting the limited influence of dual plate fixation on forearm rotation. Based on the findings of Girard et al., the posterolateral region of the radial neck is important for blood supply to the proximal radius. Excessive dissection of the soft tissues within this region may result in delayed union of the fracture[17]. In our patients, a T-shaped, 2-mm plate was placed at the anterolateral side of the radial head, which was parallel or below the articular surface. A 2-mm plate with 4 holes or a 2-mm T plate (with 2 holes at proximal end, 4 holes at distal end) was placed at the posteromedial side of the radial neck, where the articular cartilage surface was the widest and the cortical bone was the thickest. The proximal end of the plate was placed out of the articular surface, with only 1 or 2 screw used to fix the radial head. The follow-up results of this study suggest that this rigid fixation of the radial head had a limited restriction of the proximal radioulnar joint. The results of this study indicate that the dual plate technique provides more reliable stability for patients with radial head and neck fractures and has a better curative effect.

This is the first study that applied the dual plate fixation to the radial neck and head fractures. Admittedly, our study is not without limitations. First, the value of this study may be limited by the small sample size. However, radial neck fractures with comminuted radial head fractures are rare. Second, we did not include a control group. Therefore, we cannot directly compare the curative effect between unilateral plate fixation and dual lateral plate fixation. Third, we were not able to obtain the most recent radiographic images to evaluate complications such as heterotopic ossification and humeroradial joint arthritis.

Despite these limitations, we found that Mason type III–IV radial neck fractures with or without the involvement of the radial head can be treated with the dual plate technique. Further prospective, randomized studies would be helpful in determining the curative effect of dual plate fixation in the treatment of radial head and neck fractures.

Conclusions

Dual plate fixation of radial neck fractures with or without radial head involvement led to sufficient midterm results, despite a slight deficit of extension or rotation occurred in 3 of the 9 cases. We postulate that the dual plate fixation provides an alternative option for the treatment of radial head and neck fractures.

Abbreviations

ROM: Range of motion

DASH: Disabilities of the Arm, Shoulder and Hand

MEPI: Mayo Elbow Performance Index

Declarations

Ethics approval and consent to participate:

Informed consent was obtained from the patients involved in the study, and ethical approval was granted from the Ethics committee of Shanghai Sixth People's Hospital.

Consent for publication:

Consent was obtained from the patient for the use of the personal data.

Availability of data and materials:

The datasets generated and/or analysed during the current study are not publicly available due to personal information and images were included but are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Not applicable.

Authors' contributions:

KY contributed to the data collection and manuscript preparation; HQ helped with data analysis and manuscript preparation; ZQA contributed to the study design, supervision and manuscript editing.

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Figures

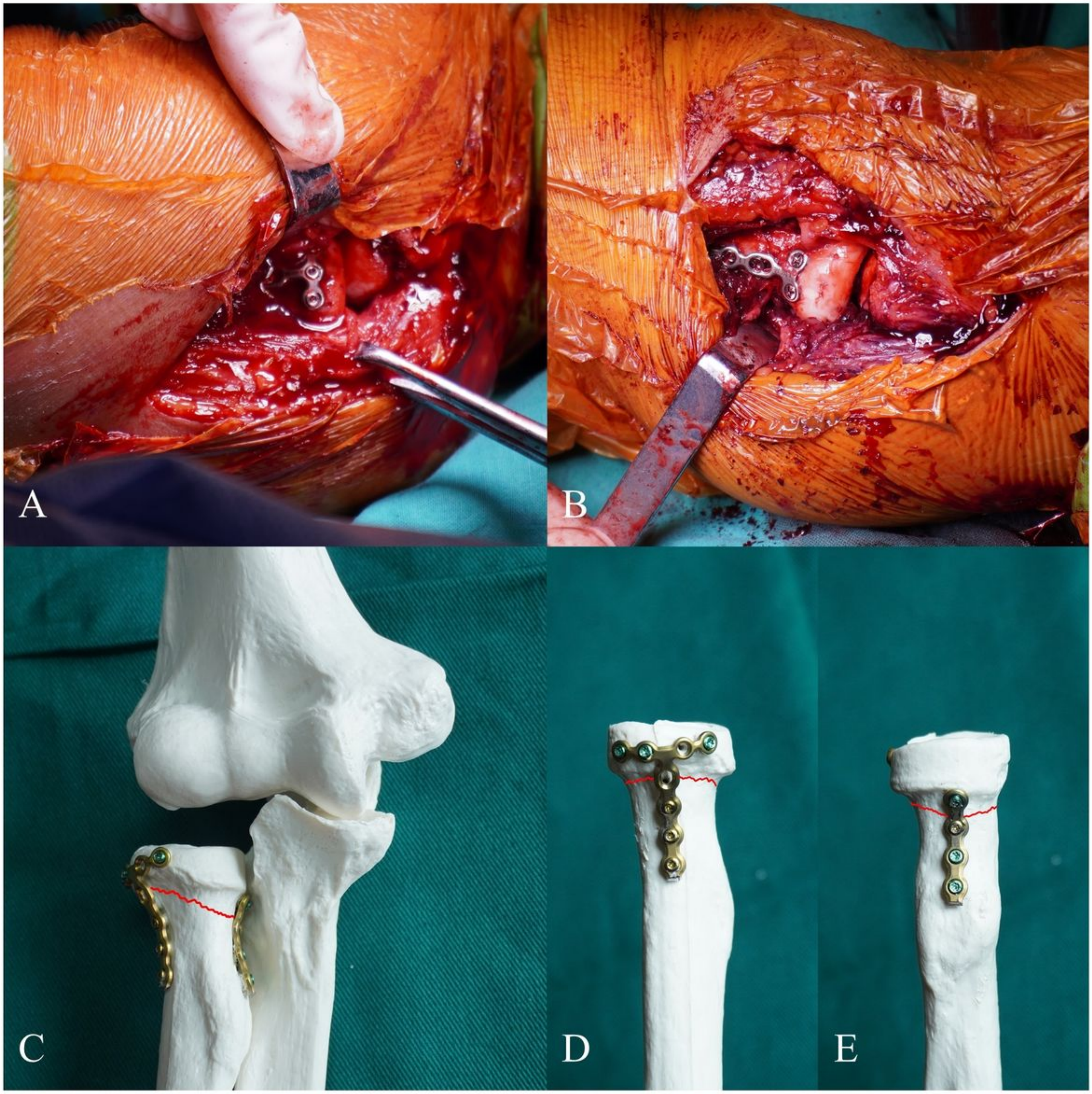

Figure 1

Intraoperative photographs show the location of the anterolateral T-shaped plate (A) and the posteromedial plate (B). Bone model shows the general location of the plates (C), the location of the anterolateral T-shaped plate (D) and the posteromedial 4-hole plate (E). The red line on the model presents the fracture line of the radial neck.

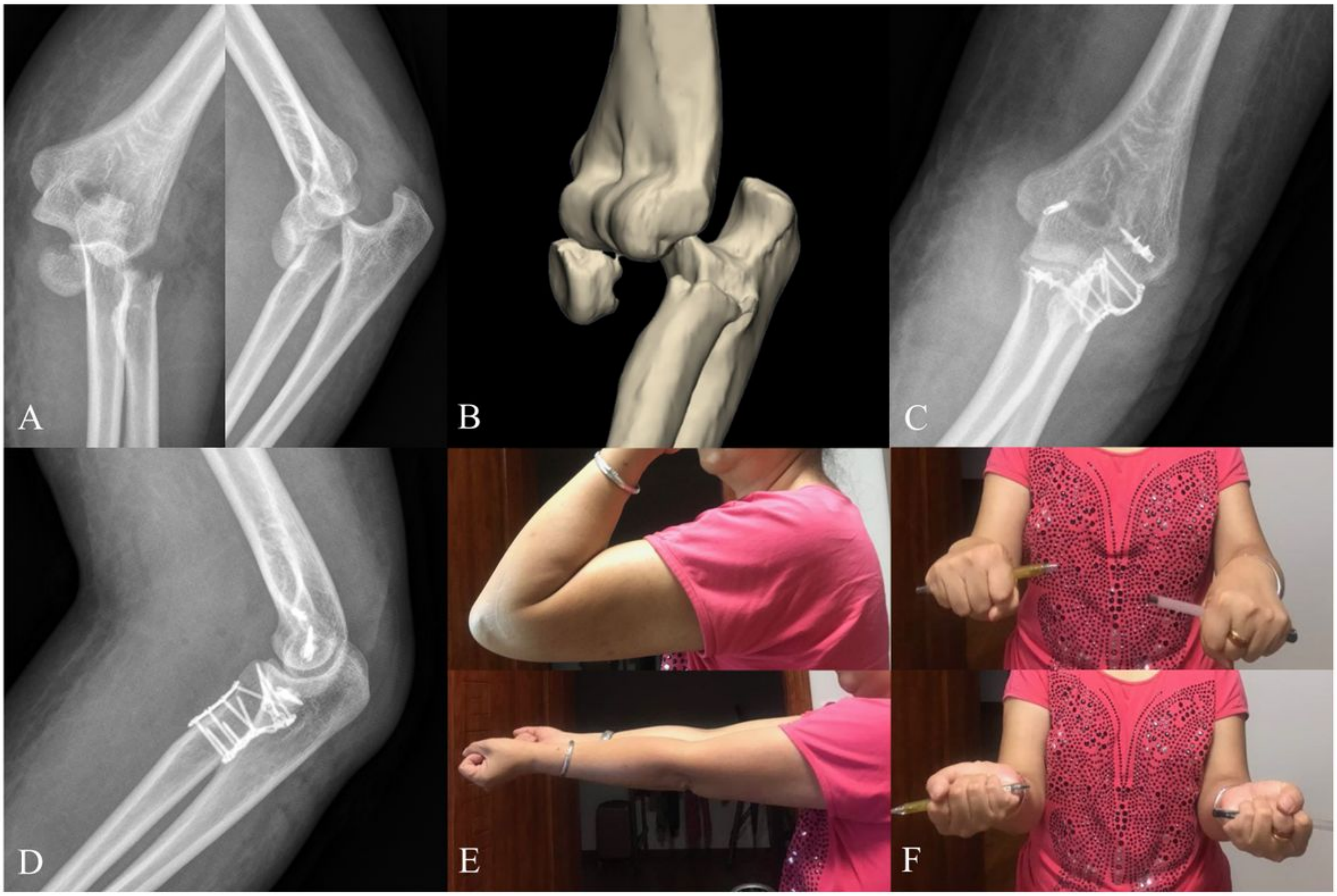

Figure 2

Case of Mason IV radial neck fracture treated with dual plate fixation and complete follow-up of the patient. X-ray views (A) and CT reconstruction (B) show the radial neck fracture with elbow dislocation. Plain films show the anteroposterior (C) and lateral (D) x-ray views after internal fixation. Photographs show the flexion and extension (E) and rotation (F) movement of the elbow after the follow-up for 42 months.