


CLINICAL ARTICLE

Minimally Invasive Treatment of Mason Type II Radial Head Fracture by Intramedullary Pinning

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Radial head fractures comprise almost one third of all elbow fractures and frequently follow a fall onto an outstretched hand with the elbow slightly flexed and the forearm in pronation^{1,2}. Mason proposed the initial classification of radial head fractures in 1954³, and defined that type I fracture, accounting for 64%–82% of radial head fractures, was a gap or marginal sector fracture with non-displacement or minimal displacement; Mason type II fractures were partial articular surface fractures with displacement; and comminuted fractures involving the whole radial head were Mason type III fractures. Broberg and Morrey provided a modification based on

Mason's original classification, and quantified that fracture displacement greater than 2 mm and fracture fragments accumulating more than 30% of the articular surface should be regarded as type II fractures⁴. It is generally agreed that fracture with no displacement or displacement less than 2 mm (type I fractures) can obtain an excellent result by conservative treatment, whereas comminuted fractures (type III fractures) potentially require open reduction and internal fixation (ORIF), radial head excision or replacement^{5–8}. For isolated displaced partial articular fractures of radial head (type II fractures), the debates of treatment over ORIF or nonoperation has not reached a consensus *via* referring to existing literature^{9,10}.

Address for correspondence Hai-lei Yin, MD, Department of Orthopaedic and Traumatic Surgery, No. 971 Hospital of the People's Liberation Army (PLA), Qingdao, China 266071 Tel: 0086-015092032878; Email: 1431951086@qq.com or gukedor@163.com**Disclosure:** The authors have no conflicts of interest to declare.

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Previously, the best choice of treatment for Mason type II fractures was radial head excision after failure of nonoperative treatment¹⁰. In the recent years, a trend toward ORIF of Mason type II radial head fractures has emerged. This is at least in part because the integrity of the radial head, which forms the one part of the humeroradial joint, is essential for elbow biomechanics and load transferring. Moreover, the improvement of surgical techniques and new implants make ORIF producers more common in type II fractures. However, a good anatomical reduction of radial head can be achieved by ORIF to prevent the possibility of the development of arthritis, which is associated with a higher incidence of avascular necrosis, heterotopic ossifications, posterior interosseous nerve injury, joint stiffness, infection, and limited elbow function—particularly in those cases where the implants have to be positioned out of the safe zone^{6,7}.

At present, a fracture with a mechanical block or fracture fragment displacement of greater than 2 mm is usually referred as a criterion to evaluate the possibility of operation. But different parameters and factors, such as fracture time, fracture type, fracture stability, displacement of fragment, and accompanied other injuries, should be taken into account when making a treatment decision⁹. Mid- and long-term follow-up have demonstrated good to excellent results of patients with type II radial head fractures treated nonoperatively^{9,11}. Nonoperation can preserve normal kinematics of the elbow and avoid related complications associated with ORIF, yet some complications, such as elbow pain and functional limitations, are reported due to the post-traumatic arthritis secondary to displaced fractures¹².

In view of the above-mentioned literature, this study aims to: (i) offer an idea that intramedullary pinning might be a practicable choice for the treatment of Mason type II radial head fractures. It was Metaizeau et al. who first proposed intramedullary pinning as a surgical option to treat pediatric radial neck fractures¹³; (ii) this technique, which allows less complications related to ORIF and supports closed reduction, differs from conservative treatment as well as ORIF procedures. A systematic review of literature demonstrated that the analysis of intramedullary pinning in the treatment of radial head fracture has not been reported; and (iii) therefore, the purpose of this retrospective case series is to evaluate the functional outcome of isolated displaced partial articular fractures of radial head (Mason type II fractures) treated by intramedullary pinning using titanium elastic nails (TEN).

Materials and Methods

Inclusion and Exclusion Criteria

Inclusion criteria: (i) The patient had a partial articular radial head fracture that should be in one piece; (ii) fracture fragments accumulated more than 1/3 articular surface of radial head and displaced greater than 2 mm; (iii) surgical operation of the patient should be applied by intramedullary

pinning using TEN; and (iv) the follow-up time should be at least 12 months.

Exclusion criteria: (i) any other fractures or ligament injuries around the elbow under the monitor of CT scan and MR imaging; (ii) the time from injury to operation was more than 2 weeks; and (iii) the patient had a pre-injury mobility dysfunction.

Participants

From May 2013 to March 2017, 25 consecutive patients with Mason type II radial head fractures were identified at our institution. Referring to inclusion and exclusion criteria, three patients underwent treatment with ORIF, and three patients had coronoid process fractures, and two patients had an olecranon fracture. Moreover, three patients were associated with lateral collateral ligament injury, and two patients were lost to follow up. Thus, a total of 12 patients with isolated Mason type II radial head fractures in this study were identified and collected.

The patients comprised eight men and four women with the mean age of 40 years (range, 21–58 years). Six injuries were due to falling from standing height; four injuries were the result of falling during sports activities; two injuries were due to traffic accidents. The duration of injury to surgery was 3.2 days (range, 2–8 days). The medical ethics committee of our institution approved this study, and informed consent was obtained from all patients.

Surgical Technique

All patients were placed in the supine position with the injured limb abduction under brachial plexus nerve block. A 1.0 cm skin incision that was proximal to radial styloid process about 2 cm was made and soft tissues were retracted carefully to avoid injuring the superficial branch of radial nerve. The lateral radial cortex was exposed and perforated using a specialized bone awl to make an entry point for the

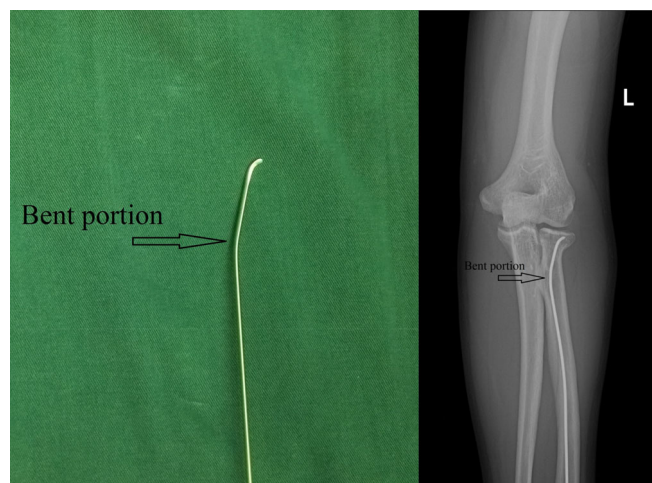


Fig. 1 The bent point in the vicinity of radial tuberosity.

insertion of the TEN. The tip of TEN was bent approximately 25–30 degrees, allowing the bent point in the vicinity of radial tuberosity (Fig. 1).

The TEN was introduced into the radial medullary canal with the tip towards anterolateral direction and hammering slowly upward until the tip fixed the fragment. Most collapsed articular surface of radial head could be repositioned gradually with the fragment lifting up. In addition, joystick technique using a percutaneous wire might be helpful if the reduction was unsatisfactory (Fig. 2). The end of the TEN was cut and skin closed after achieving satisfactory reduction under the fluoroscopic control.

Postoperative Management

All patients were given ice therapy and routine antibiotics to prevent infection postoperatively. Sling for 1 week was carried out in every patient, and then early mobilization. Sporting activities and other vigorous activities were restricted for 3 months. Each patient was followed up clinically and radiologically 3, 6, and 12 months postoperatively for the assessment of elbow function, the status of bone healing, and complications.

Outcome Evaluation

The clinical evaluation consisted of clinical examination and radiographic evaluation, which was carried out by two orthopedic surgeons who were not involved in the operation.

Range of Motion (ROM) of the Elbow

The ROM of the elbow was measured by a standard goniometer, which includes the flexion and extension of the elbow, pronation and supination of the forearm. The measurement results on the injured side compared with uninjured side could reflect the recovery extent of elbow joint function.

Shortened Disabilities of the Arm, Shoulder, and Hand Questionnaire (QuickDASH)

The QuickDASH was intended for assessment of upper extremity disorders, which consisted of 11 items from the original 30-item disabilities of the arm, shoulder, and hand

(DASH) questionnaire. Each item in the disability scale could be divided into five response options including much better, somewhat better, unchanged, somewhat worse, and much worse. The scale scores had a minimum of 0 points (no disability) and a maximum of 100 points (most severe disability)¹⁴.

Visual Analogue Scale (VAS)

The VAS scoring system was used to estimate the pain level of the patients. The VAS pain score = 0 was considered as painless; 0–3 was mild pain that did not affect sleep; 4–6 was moderate pain and patients were able to sleep; and 7–10 was intense pain and patients were unable to sleep.

Mayo Elbow Performance Score (MEPS)

The MEPS was performed to evaluate postoperative recovery of elbow function, which mainly included four aspects: pain, function of sports, stability of elbow, and daily activities. A total score <60 was considered as poor, 60–74 as fair, 75–89 as good, and 90–100 as excellent¹⁵.

Complications

Clinical examinations and radiographic evaluations were performed to evaluate joint stiffness, union status, fixation failure, heterotopic ossifications, and post-traumatic arthritis. The radiographic evaluation consisted of anteroposterior and lateral radiographs of elbow. Union status of the fracture was defined as fracture line becoming blurred with a continuous callus passing through it. Whereas, nonunion was considered as persistence of the fracture line 6 months after operation. The fixation failure was pullout of the TEN from the marrow cavity.

Statistical Analysis

All statistical analyses were performed using SPSS 22.0 software (IBM Software, Chicago, USA). All quantitative data was assessed for statistical significance by use of the Student *t*-test. The level of significance was defined as $P = 0.05$.

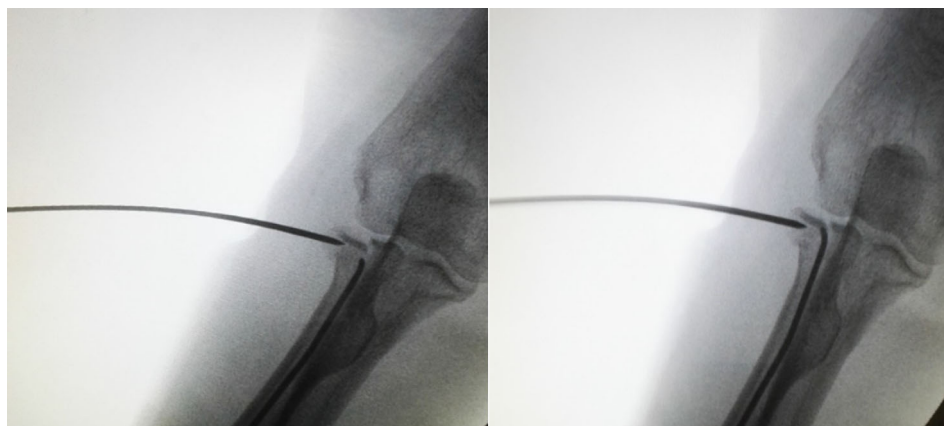


Fig. 2 Reduction of fragment assisted by percutaneous wire.

TABLE 1 Patient demographics and clinical evaluation results

Case No.	Sex/ Age (years)	Follow-up (months)	TEN size (mm)	Flexion -extension of elbow (°)	Forearm pronation (°)	Forearm supination (°)	Status of union	VAS	MEPS	Quick-DASH	Complication
1	Male (52)	25	1 × 2.5	140	85	85	United	0	95	0	None
2	Male (21)	24	2 × 2.0	145	86	90	United	0	100	0	None
3	Female (33)	26	1 × 2.0	138	90	90	United	0	95	0	None
4	Male (44)	18	2 × 2.0	144	90	85	United	0	100	0	None
5	Male (35)	24	1 × 3.0	140	82	90	United	0	100	0	None
6	Female (47)	22	2 × 2.0	138	85	85	United	0	90	0	None
7	Male (57)	15	2 × 2.0	136	85	89	United	2	85	7	Affection of the superficial radial nerve
8	Female (58)	24	1 × 2.5	135	85	85	United	0	90	7	None
9	Male (37)	12	2 × 2.0	140	90	85	United	0	95	0	None
10	Male (36)	20	2 × 2.0	138	85	90	United	0	95	0	None
11	Male (48)	24	2 × 2.0	140	90	90	United	0	95	0	None
12	Female (50)	28	1 × 2.0	135	85	85	United	2	85	14	Affection of the superficial radial nerve

Note: VAS, Visual Analogue Scale; MEPS, Mayo Elbow Performance Score; DASH, Disabilities of the arm, shoulder and hand

Results

A total of 12 patients were followed up with a mean of 21.8 months (range, 12–28 months). Detailed information for each case was summarized in Table 1.

ROM of the Elbow

The average ROM in elbow flexion-extension was $139.08^\circ \pm 3.14^\circ$ on the injured side and $140.16^\circ \pm 3.01^\circ$ on the uninjured side ($P = 0.398$). The forearm pronation was $86.50^\circ \pm 2.75^\circ$ on the injured side and $87.83^\circ \pm 2.12^\circ$ on the uninjured side ($P = 0.197$). The forearm supination was $87.41^\circ \pm 2.53^\circ$ on the injured side and $88.17^\circ \pm 1.95^\circ$ on the uninjured side ($P = 0.425$, Table 2). None of the patients were affected in daily life.

MEPS Score

According to the MEPS, we had 10 excellent and two good results, and the MEPS score increased significantly from 34.75 ± 8.56 points preoperatively to 93.75 ± 5.28 points (range, 85–100) at the latest follow-up ($P < 0.05$).

QuickDASH Score

The QuickDASH score were 77.26 ± 5.36 respectively before surgery, and these scores revealed good to excellent results

with 2.33 ± 4.56 points (range, 0–14) at the latest follow-up ($P < 0.05$).

VAS for Pain

The VAS for pain decreased from 4.98 ± 3.17 before surgery to 0.33 ± 0.78 (range, 0–2) at the latest follow-up ($P < 0.05$). Two patients had a minor complication (Case 7, 12), and complained about a constant affection of the superficial branch of radial nerve at the area of the entry point of the TEN. The intensity of two on the VAS for pain rating had been described in Table 1.

Complication

All the surgical incisions healed with primary closure, and no complications, such as wound infection, trauma of blood vessels and nerve, pullout of the TEN, and fragment re-displacement, were observed. Only two patients have a minor affection of the superficial branch of radial nerve. The TEN in all cases were removed with osseous healing of the radial head. Both good clinical and radiological results in all patients were achieved without nonunion or delayed union of fractures, instance of elbow pain, joint stiffness, heterotopic ossification, and post-traumatic arthritis until last follow-up (Figs. 3 and 4).

Discussion

Sandmann *et al.* first proposed intramedullary pinning was not only suitable for children, but also satisfactory in the treatment of adult radial neck fractures¹⁶. In the present series, intramedullary pinning technique is applied in adult radial head fracture, especially in Mason type II radial head fractures where the best choice of treatment is still controversial. A minor amount of literature reported on this previously.

TABLE 2 ROM of postoperative injured elbow and uninjured elbow joint (mean ± SD, °)

Motion	Postoperative injured elbow	Uninjured elbow	P
Flexion-extension of elbow	139.08 ± 3.14	140.16 ± 3.01	0.398
Forearm pronation	86.50 ± 2.75	87.83 ± 2.12	0.197
Forearm supination	87.41 ± 2.53	88.17 ± 1.95	0.425

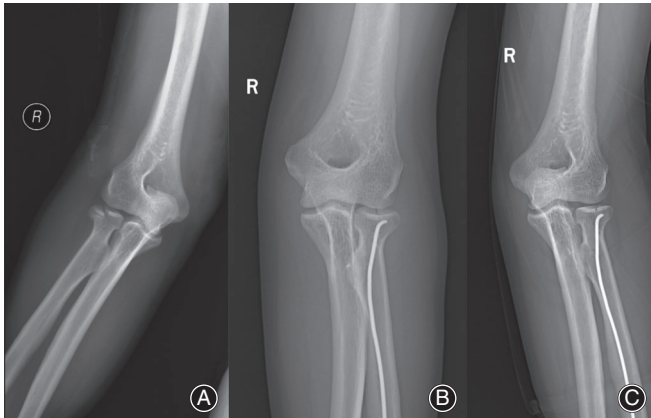


Fig. 3 (A) Anteroposterior radiograph of a 52 years old man who fell from standing height, suffering a Mason type II radial head fracture (Table 1, Case 1). (B) Anteroposterior radiograph of post-operation showed a good reduction of displaced articular surface was achieved after TEN insertion. (C) Anteroposterior radiograph showed bone union without secondary displacement at 12 weeks.

Debates Over Treatment of Type II Radial Head Fractures

Up to now, there is no objective evidence to support 2 mm as a clear cut-off value for conservative treatment versus ORIF procedures¹⁰. The development of biomechanical studies and surgical instruments has made more surgeons prefer ORIF to prevent the possibility of the development of arthritis¹⁷. Pearce and Gallannaugh reported good outcomes in Mason type II radial head fractures studied *via* the use of

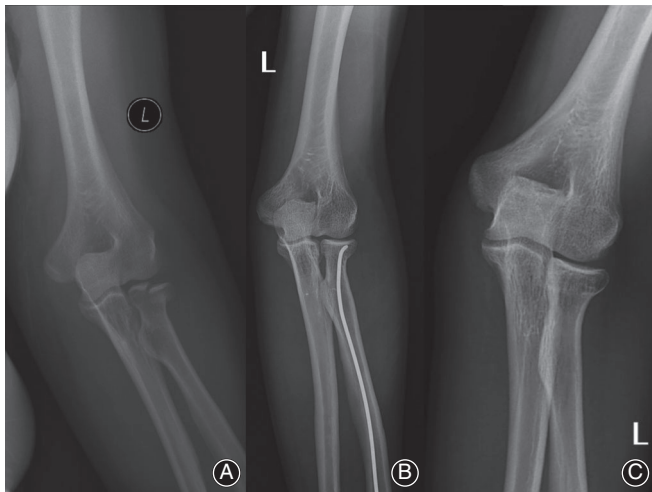


Fig. 4 (A) Anteroposterior radiograph of a 35 years old man who fell during sports activities, suffering a Mason type II radial head fracture (Table 1, Case 5). (B) Anteroposterior radiograph showed fracture healing without secondary displacement at 9 weeks. (C) Anteroposterior radiograph did not find any degenerative changes at 2 years follow-up. The patient had a full ROM without elbow pain.

Herbert screws, then surgery was suggested¹⁸. Burkhart *et al.* proposed operation to avoid the occurrence of arthritis due to intra-articular fracture¹⁹. Demiroglu *et al.* demonstrated that anatomical reduction of radial head fractures treated with ORIF using screws could obtain a successful outcome in young and middle-aged adults²⁰. Although a good anatomical reduction can be achieved by ORIF procedures, it is possibly associated with an incidence of heterotopic ossifications, posterior interosseous nerve injury, joint stiffness, and other complications^{21–24}.

Nonoperation can preserve normal kinematics of the elbow and prevent complications related to ORIF. Mid- and long-term follow-up has indicated that the majority of patients undergoing conservative treatment have a lower incidence of complication, such as heterotopic ossification¹¹. Duckworth *et al.* described good to excellent results obtained in 96% of their cases treated non-surgically²⁵. Yoon *et al.* did not find significant clinical benefits with ORIF compared to conservative treatment⁹. However, due to the absence of reduction of intra-articular fracture, some defects affecting function might occur after no surgical treatment. Khalfayan *et al.* found out that the patients who underwent no operation had more pain along with functional limitations¹². In a study on 52 patients managing conservative treatment, Guzzini *et al.* reported that some complications occurred, such as elbow occasional pain, instability of the elbow, loss of grip strength, and degenerative changes, which could be related to osteoarthritis secondary to the intra-articular fracture²⁶.

Strengths of Intramedullary Pinning vs both ORIF and Conservative Treatment

Compared with conservative treatment, intramedullary pinning technique is able to achieve closed reduction that avoids potential progress of osteoarthritis. For the majority of Mason type II fractures, the resultant combination of valgus, axial, and external rotatory loading mechanisms lead to the anterolateral margin of the radial head susceptible to shearing type injury^{1,2}. Therefore, controlling the orientation of the tip towards anterolateral direction, the majority of such fractures in our case series can be repositioned gradually with the fragment lifting up. Moreover, the principle of using K-wire we manipulated to assist reduction of fracture in radial head is different from pediatric radial neck fracture. For pediatric radial neck fractures, the inserted K-wire, as a lever, is positioned to touch the site of the fracture site, and then radial neck fracture is reduced²⁷. By contrast, a horizontal pressure and downward warping on the K-wire is given in our study to form a “pushing-jacking” effect for reduction of radial head fracture.

The ORIF procedures are able to make a solid internal fixation effect on the fracture site and conform to the AO principles of internal fixation. However, it may result in the strong possibility of excessive dissection, periosteal stripping, soft tissue injury, and even damaging the blood supply of the radial head during operation. Intramedullary pinning bears

the advantages of no dissection on the fracture site without injury on the surrounding soft tissue and the blood supply of the radial head, which accords with BO principles of internal fixation. Previously reported in the literature, a good therapeutic effect can be achieved by percutaneous poking reduction and external fixation alone²⁸. This is due to the fact that uninjured soft tissue can form an effect of “soft tissue splint” limiting transverse displacement of radial head, which makes the fracture stable once reduced. In addition, intramedullary pinning in the medullary cavity can offer an axial support through three-point supporting to correct axial displacement. The tip of the nail is the first point, which can be embedded in the cancellous bone under the articular surface. The bent point in the vicinity of radial tuberosity is the second point. The third point is the end of the nail. The anti-bending and anti-rotation properties of the TEN can be further enhanced by three-point support, and the axial displacement of fractures can be corrected and fixed. Thus, under the control of both axial support and transverse limit, no fragment re-displacement in our study is observed.

Limitations of Intramedullary Pinning

Although the results of our study show that intramedullary pinning is an alternative surgical method for Mason type II radial head fracture, there are still some limitations. Radial head fractures may be isolated or may be part of a more broader elbow injury, which is commonly associated with other injuries, including medial or lateral collateral ligament rupture, interosseous membranes injury, olecranon fracture, or coronoid fracture². Intramedullary pinning is not enough for the treatment of compound damage of radial head fracture. Thus the injured elbow must be carefully evaluated before the application of the TEN to rule out associated ligamentous and bony pathology. Furthermore, it is reliant on sufficient bone stock to maintain the hold the TEN in the radial head, as too small or comminuted fractures mean that

the TEN may be unable to pass into the head without displacing the fragment further. For those patients with serious osteoporosis, intramedullary pinning technique should be contraindicated because the TEN might cause more damage to the stability of the fracture site.

Combination of ORIF with Intramedullary Pinning

For now, we suggest that this technique should only be used in isolated partial articular radial head fractures, as we are confident that a firm fixation cannot be achieved just by using the TEN in some complex injuries. However, a sort of hybrid method seems conceivable: for comminuted radial head or radial neck fractures, the fracture site can be stabilized by the use of the TEN after open reduction of the radial head using screws or plate fixation. This technique might be especially applicable in some cases where the fracture is still unstable after hardware placement. Future research will prove whether the combination of ORIF with intramedullary pinning is possible.

Conclusion

To summarize, the present data suggests that Mason type II radial head fractures can be treated with TEN to achieve good to excellent outcomes without other related complications that were reported in previous literature. Although two patients have a minor complication, there is reason to suggest that intramedullary pinning technology, as a minimally invasive surgery, might partly make up for some deficiencies between conservative treatment and ORIF procedures. This technology gives the surgeon another option for such injury. Because of the small number of cases in this study and the lack of a comparative group of cases treated with other techniques, it is not definite whether this novel technique is beneficial compared to other treatments. Thus, the effect of this technology needs to be accessed by further accumulation of patients.

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