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Original Article

The clinical efficacy of the minimally invasive treatment of Mason type II radial head fractures using intramedullary fixation with double titanium elastic nails

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Abstract: Radial head fractures (RHFs) occur most frequently among all elbow fractures. Current treatments pose several limitations for the Mason type II radial head fractures. This study was performed to evaluate the clinical efficacy of a new minimally invasive treatment for Mason type II radial head fractures using intramedullary fixation with double titanium elastic nails. Between January 2018 and December 2019, our group used double titanium elastic intramedullary nails as a minimally invasive treatment for 32 cases of Mason II type radial head fractures. After the treatments, we summarized and conducted a retrospective analysis to evaluate the surgical operation itself, the quality of the fracture reductions, the fracture healing, and any complications. The Mayo elbow function scores (MEPS) and the visual analog scale (VAS) pain scores were used to evaluate the clinical efficacy of this approach. All the patients recovered from their surgeries without any complications. We followed all the cases for an average of 12 months. The elbow extension range of motion was 5 degrees (range: 0-15 degrees), the elbow flexion range of motion was 140 degrees (range: 135-146 degrees), and the average forearm pronation range of motion was 84.1 degrees (range: 78-90 degrees). The average forearm supination range of motion was 80.4 degrees (range: 75-85 degrees). All the fractures healed (a 100% healing rate), the MEPS score was 96.7 (range: 85-100), and the MEPS ratings of excellent and good were both 100%. The VAS pain scores ranged from 0-1. The minimally invasive treatment of Mason type II radial head fractures using intramedullary fixation with double elastic nails proved to be a simple approach with a relatively short operation time. It required only a small incision with little trauma and had few complications, so it is worth consideration for wider use.

Keywords: Radial head fractures, Mason type II, double titanium elastic nails, minimally invasive, intramedullary fixation, clinical efficacy

Introduction

Radial head fractures (RHFs) account for approximately one third of all elbow fractures [1, 2]. Epidemiological studies have shown that the age of onset is represented by a bimodal distribution, with the ages primarily between 20 and 60 years [3, 4]. Clinically, the treatment of radial head fractures is often determined according to the Mason classification [5]. A Mason type I fracture is nondisplaced, and conservative treatment is used in these patients with a good clinical effectiveness. Mason types III and IV fractures are types of comminuted intra-articular fractures with/without elbow joint dislocation. For these fracture types, most scholars recommend surgical treatment [6]. At present, the best treatment options for Mason types I, III and IV fractures have been clear and without debate; however, the best treatment for Mason type II fractures remains controversial [7].

The treatment options for Mason type II radial head fractures can be divided into conservative and surgical treatment approaches. Some scholars believe that conservative treatment is feasible for fracture site displacements that

are <2 mm [8]; however, they also point out that while conservative treatment may provide better short-term effects, there are many complications later, and surgical intervention may be needed for severe cases [9]. At present, and in order to avoid the occurrence of complications, most scholars suggest that Mason type II radial head fractures undergo surgical treatment. The surgical methods used include screws, plates, Kirschner wire, or biodegradable screw fixation [10]. Despite these options, there is no consensus on which surgical method is the best approach. Although open reduction and internal fixation achieve good anatomical reduction, the significant tissue damage that can result may lead to heterotopic ossification, radial nerve injury, elbow stiffness, and other complications [11]. Moreover, the postoperative scar is significant and may affect the patient's psychology in serious cases [12-15].

Recently, some studies have found that minimally invasive treatment for Mason type II fractures with a single elastic titanium nail can achieve a certain clinical effectiveness [16]. However, our team believes that a single elastic titanium nail may have shortcomings, including insufficient holding force and limited anti-rotation ability. As a result, it is unable to maintain the three-dimensional stability of the fracture site. Therefore, based on our clinical experience and a deep literature analysis of surgical treatment approaches for radial head fractures, our team summarized and proposed an innovative technology-double elastic titanium nails-to use in the minimally invasive treatment of the Mason type II radial head fractures. Critically, this approach achieved an excellent clinical effectiveness. Of the 32 patients with Mason type II radial head fractures treated with this approach, all were successfully treated. Here, we demonstrate the remarkable clinical effectiveness of double elastic titanium nails in the minimally invasive treatment of Mason type II radial head fractures.

Materials and methods

Ethics statement

This retrospective study was approved by the Ethics Committee of Shenzhen People's Hospital at Jinan University (*approval number: LL-KT-2018*). All the volunteers gave their informed consent prior to participating in the study.

General information

Between January 2018 and December 2019, our group used double elastic intramedullary nails for the minimally invasive treatment of 32 cases of Mason II type radial head fractures. After the surgeries, we summarized and conducted a retrospective analysis to evaluate the surgical operation itself, the quality of the fracture reduction, and the fracture healing and complications, The Mayo elbow function scores (MEPS) and the visual analog scale pain scores (VAS) were used to evaluate the clinical efficacy of this approach.

The inclusion criteria and exclusion criteria

Inclusion criteria: (1) Patients with Mason II radial capitulum fractures with a displacement of the fracture site more than 2 mm. (2) Patients with the clinical manifestations and corresponding signs of Mason II fractures and whose fracture types were confirmed through both preoperative X-rays and CT scans (**Figure 1**). (3) The operation method was closed reduction and double elastic titanium nail intramedullary fixation.

Exclusion criteria: (1) Patients with pen fractures and/or ipsilateral limbs with other fractures, ligament injuries, and/or severe skin and/or soft tissue injuries. (2) Pathological fractures. (3) Old fractures that were first seen more than three weeks after the injury.

Surgical technique

The patient was placed in a supine position and the affected limb was abducted on the operating table after satisfactory anesthesia and disinfection. The diameter of the narrowest part of the radial medullary cavity was determined according to the pre-operative imaging examination, after which the appropriate size of the elastic titanium nail was selected. The length of the incision was approximately 1-2 cm. After the skin incision, the soft tissue around the subcutaneous skin was carefully separated to avoid damaging the superficial branch of the radial nerve to the radial cortex. A proper Kirschner wire was used to drill the hole at the lateral part of the radial shaft; the hole was then opened with a mouth opener. The tip of the elastic titanium nail was

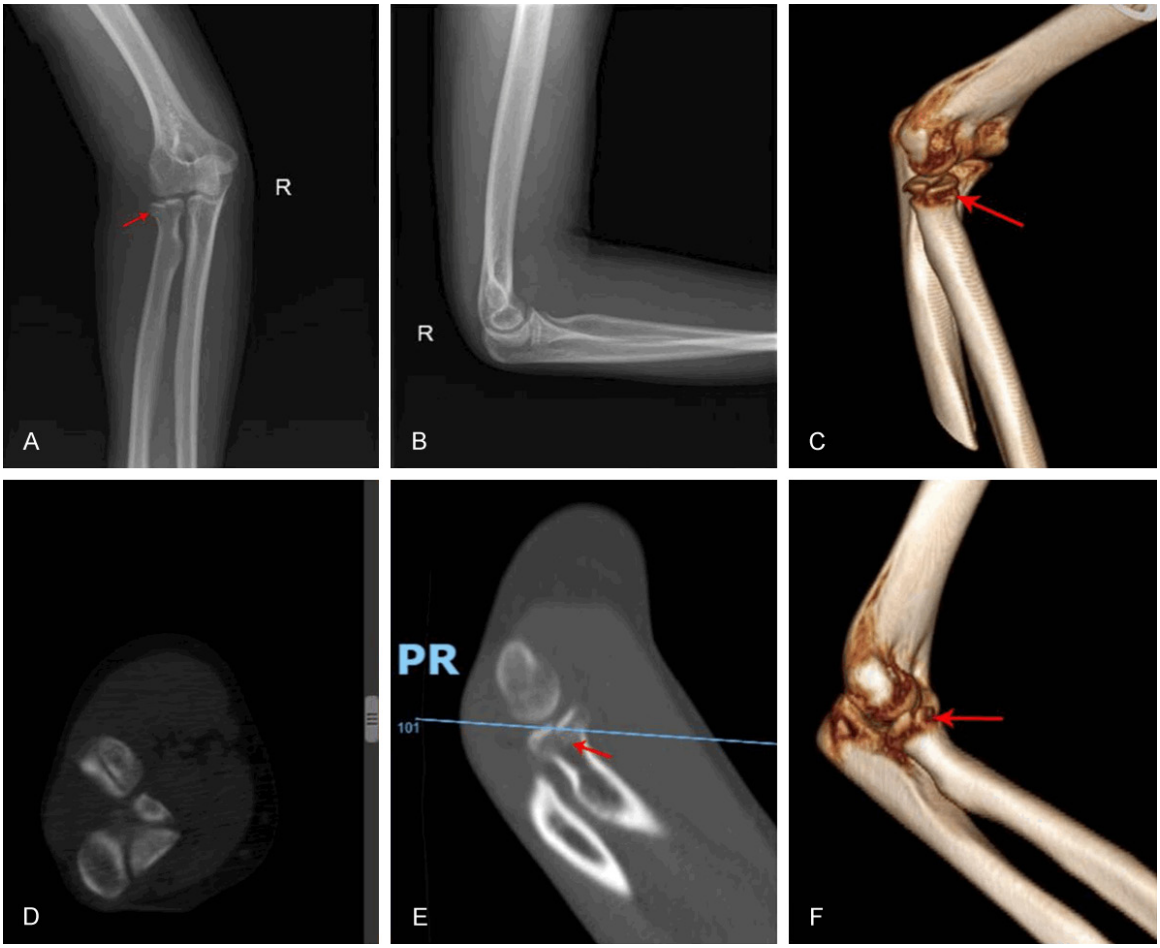

Figure 1. Preoperative patient imaging data. A 31-year-old female patient with a Mason type II fracture of the right radial head that was caused by a falling injury. The preoperative X-ray showed a radial head fracture in the anteroposterior (A) and lateral (B) positions, with a significant displacement of the fracture site. The preoperative CT, sagittal (D), coronal (E) and three-dimensional reconstruction (C, F) confirmed that the radial head fracture had fracture fragments displaced anterolaterally with joint surface irregularity (The red arrow illustrates the position of the radial head fracture site).

oriented to the anterolateral upper side, retrogradely and slowly upward along the medullary cavity to the radial neck. At this time, the orientation of the needle tip was adjusted according to the displacement direction of the fracture site. The tail of the needle was struck to make the elastic titanium nail pass through the radial neck to the radial head. At this time, the fracture block was gradually lifted and reduced by prying the reduction of the elastic titanium nail tip, which was located 2 mm below the subchondral bone of the capitulum radius. During this process, care was taken to ensure the elastic titanium nail did not penetrate the articular surface.

A second elastic titanium nail was then prebent according to the above method, and opened at another plane on the inner side of the radial shaft. The tip of the intramedullary nail was inward up to the fracture site. As previously described, the elastic titanium nail was penetrated to 2 mm under the subchondral bone of the radial capitulum. At this time, the tips of the two elastic titanium nails were opened to support the fracture site, functioning like a lift. The reduction of the fracture and the position of the elastic titanium nail were confirmed using X-rays during the operations (**Figure 2**).

Postoperative management

All the patients were administered first generation cephalosporin antibiotics to prevent infection 30 minutes before each operation,

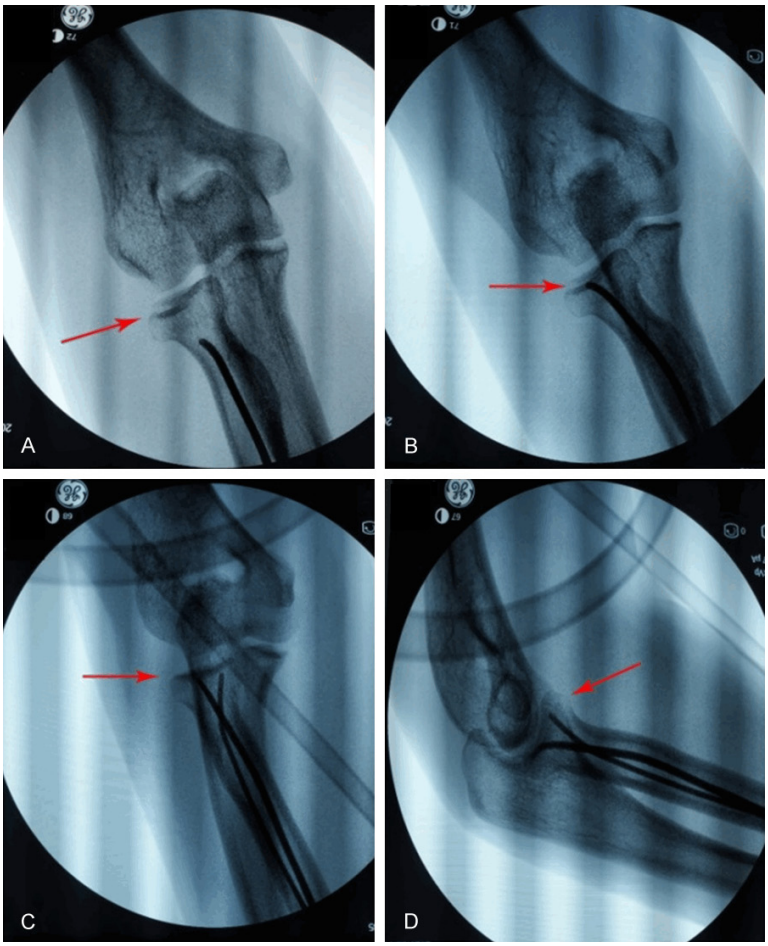

Figure 2. Intraoperative X-ray monitoring of the elastic titanium nail implantation process and fracture reduction. A. An intraoperative X-ray showed that a single elastic titanium nail reached the radial neck through the medullary cavity, and the fracture site was still displaced. B. After tapping the nail tail, the elastic titanium nail passed through the radial neck to the radial head, which allowed for a prying reduction of the fracture site. However, there remained some unevenness of the articular surface. C. The anteroposterior X-ray showed that after the second elastic titanium nail was used to fix the fracture, the two elastic titanium nail tips were opened and held up to maintain the anatomical reduction of the fracture. D. The lateral X-ray showed that the fracture site of radial head had been anatomically reduced, and the position of the two elastic titanium nails was satisfactory (The red arrow illustrates the position of radial head fracture site).

non-steroidal anti-inflammatory and analgesic drugs (NSAIDs) with ice compress for 48 hours after each operation to relieve swelling. All the patients were also advised to begin functional exercises on the second day after the operation.

Evaluation criteria of the clinical effectiveness

The intraoperative blood loss and the operation times were recorded. The quality of the fracture reductions, the fracture healing, and the complications were analyzed. The Mayo elbow function scores (MEPS) and the visual analogue scale (VAS) scores were used to evaluate the clinical results.

The average follow-up time of all the patients was 12 months. The patients were followed up at 1, 3, 6, and 12 months after the operation. The preoperative and postoperative pain changes were compared along with an evaluation of the elbow joint function, the fracture healing, and the complications.

The pain scores were determined using the 10 points visual analogue scale (VAS) [17]. A score increase indicated more serious pain and we classified the pain into the following ranges: (1) Scores of 2-4 indicated mild pain that did not affect daily life. (2) Scores 5-7 indicated moderate pain that affected the patient's sleep, but remained bearable, and (3) Scores of 8-9 indicated severe pain, which was intolerable and affected appetite and sleep.

The Mayo Elbow Performance Score (MEPS) includes pain (45), range of motion (20), stability (10) and daily function (25). According to the patients' elbow function, 90 points or more was considered excellent function, 75-89 points indicated good function, 60-74 points indicated average function, and <60 points indicated poor function [18].

Statistical analysis

The data were analyzed using SPSS 18.0 statistical software (SPSS Inc., USA). The measurements were expressed as the means ± standard deviations (SD). The comparisons between groups were performed using one-way

Table 1. The demographic characteristics of the patient cohort

Case	Sex/Age	Mechanism of injury	Range of joint motion (degrees)				MEPS	VAS	Overall result
			Extension	Flexion	Pronation	Supination			
1	M (21)	Fall	0	140	89	83	100	0	Excellent
2	F (34)	Fall	5	139	78	80	85	1	Good
3	M (22)	Traffic accident	5	138	83	81	95	1	Good
4	M (31)	Fall	5	138	80	81	95	0	Good
5	F (22)	Traffic accident	10	136	84	83	85	1	Good
6	M (29)	Fall	5	140	89	77	95	0	Good
7	F (22)	Traffic accident	0	140	88	78	100	0	Excellent
8	M (33)	Fall	15	138	81	80	95	1	Good
9	M (30)	Traffic accident	0	141	86	75	100	0	Excellent
10	M (26)	Fall	10	140	80	77	95	1	Good
11	F (24)	Traffic accident	5	140	86	79	95	1	Excellent
12	M (25)	Fall	5	142	83	82	95	1	Good
13	F (29)	Traffic accident	0	144	84	85	100	0	Excellent
14	M (26)	Fall	0	143	83	82	100	0	Excellent
15	F (31)	Fall	0	146	84	83	100	0	Excellent
16	F (27)	Fall	0	143	88	78	100	0	Excellent
17	F (25)	Traffic accident	5	140	90	82	100	0	Excellent
18	M (34)	Traffic accident	5	144	90	82	100	0	Excellent
19	F (30)	Fall	5	141	85	80	100	0	Excellent
20	M (24)	Fall	0	142	87	80	100	0	Excellent
21	F (31)	Traffic accident	5	135	82	81	95	1	Excellent
22	M (28)	Fall	10	140	87	85	100	0	Excellent
23	F (21)	Fall	10	142	87	80	100	1	Excellent
24	M (26)	Fall	0	142	82	80	100	0	Excellent
25	F (20)	Traffic accident	5	143	82	82	100	0	Excellent
26	M (25)	Fall	5	137	79	81	95	1	Excellent
27	F (29)	Traffic accident	10	137	86	80	95	1	Excellent
28	M (24)	Traffic accident	10	139	83	79	95	1	Excellent
29	F (27)	Fall	10	141	82	79	100	0	Excellent
30	M (33)	Traffic accident	5	138	87	81	95	0	Excellent
31	F (28)	Traffic accident	5	142	81	82	100	0	Excellent
32	M (27)	Fall	5	137	78	75	85	1	Good

ANOVA followed by Student's unpaired t-tests, and the count data were analyzed using χ^2 tests. *P*-values less than 0.05 were considered to indicate statistically significant differences, and *P*-values less than 0.01 and 0.001 were considered to be highly significant.

Results

A total of 32 patients were selected for this study and all the patients had excellent recoveries. Detailed information and the postoperative recoveries of all the patients are shown in **Table 1**. The average age of the patients was 27 years old (range 20-34), with 17 cases being male (53%) and 15 cases being female (47%). The fracture causes were traffic accident injuries in 14 cases (43%) and falls in 18 cases (56%). The average time from injury to operation was 7.3 days (7-10 days). The average operation time was 24.5 (10-65) min, and the average intraoperative blood loss was 5 (2-10) ml. The genders, ages, times from injury to operation, causes of injury, operation times, and intraoperative blood losses of the included patients are shown in **Table 2**.

Clinical efficacy evaluation

During this study, we kept the abnormal parameter changes visualized in preoperative imaging within the normal range. At the end of

Table 2. Data from the patients' information and follow-up

Data from patients' information and follow-up	
Number of patients	32
Sex (male/female)	17/15
Age (average, range)	27 years (20-34 years)
Interval between injury and surgery (days)	7.3 day (7-10 day)
Fracture mechanism (traffic accident: fall)	14 (43%): 18 (56%)
Duration of operation (average, range)	24.5 (10~65) min
Mean bleeding volume	5 (2-10) ml
Duration of follow-up (average)	12 months

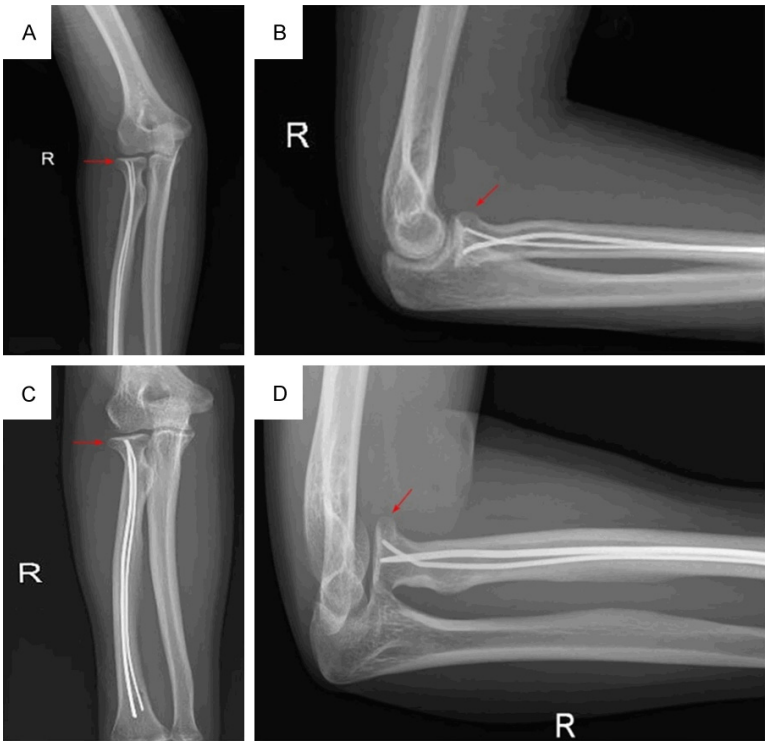

Figure 3. X-ray examination on the second day after the operation. A, B. X-ray anteroposterior and lateral views showed that after the intramedullary fixation with two elastic titanium nails, the fracture site of the radial head was anatomically reduced, and the elastic titanium nail was in a good position. C, D. Three months after the operation, the X-rays showed that the fracture line of the radial head was blurred, the fracture was completely healed, and the positions of the two elastic titanium nails were good, without any signs of loosening or fracture (The red arrow illustrates the position of the radial head fracture site).

the 12-month follow-up, an X-ray examination confirmed that all the fractures had bony unions (**Figure 3**), and all the elbow joints recovered well. The MEPS score was 96.7 (range: 85-100), and the excellent and good rates were 100%. The VAS pain scores ranged from 0-1. The elbow extension range of motion was 5 degrees (range: 0-15 degrees), the elbow flexion range of motion was 140 degrees (range: 135-146 degrees), and the forearm pronation average range of motion was 84.1 degrees (range: 78-90 degrees). The average forearm supination range of motion was 80.4 degrees (range: 75-85 degrees) (**Figure 4**). Additionally, no degeneration or traumatic arthritis was observed in the elbow joints. There were no incision or bone mineral density changes in any of the patients. None of the patients had a delayed union or nonunion.

Discussion

To our knowledge, this study is the one with the most cases of minimally invasive treatment using double elastic titanium nails. The purpose of our study was: (1) To explore an optimal surgical treatment for Mason type II radial head fractures with less injury, a firmer fixation, a satisfactory clinical effectiveness, and an easy acceptance by patients and (2) To describe the operation methods and the clinical utility of double elastic titanium nails in the treatment of Mason type II radial head fractures and to summarize and promote their application.

At present, there remain differences in the treatment of Mason type II radial head fractures, and the best surgical treatment approach has not been determined [19]. In recent years, open reduction and internal fixation have been used as effective methods for Mason type II radial head fractures [2, 20]. The first choice of treatment for this type of fracture is reduction under direct vision, which can achieve a complete anatomical reduction of the radial head and

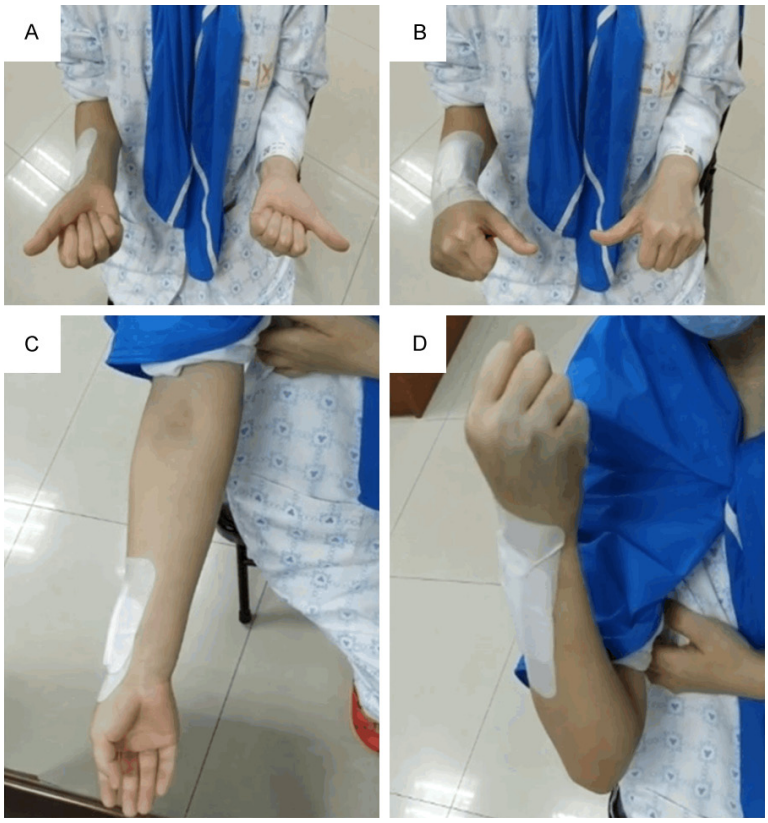

Figure 4. The patient's elbow function after the operation. On the second day after the operation, the elbow joint had good supination (A), pronation (B), extension (C), and flexion (D).

restore the function of the elbow joint to its maximal extent. However, there are some problems with this method, including a large incision and also cutting the joint capsule. This approach can result in excessive damage that affects the blood supply to the fracture site, damages the articular cartilage surface, and in severe cases-it may lead to heterotopic ossification, a deep branch injury of the radial nerve, and elbow joint injury. The complications also include stiffness. Although minimally invasive surgery with percutaneous Kirschner wire fixation has been used to treat Mason type II fractures, it has limitations, including inaccurate reduction, inaccurate fixation effects, longer post-operative time for auxiliary plaster fixation, and greater likelihood of complications. Given this, it has not been recommended for wide use. Therefore, the best surgical treatment for Mason type II radial capitulum fractures remains under debate.

In recent years, the minimally invasive concept has been increasingly promoted, including the trend towards minimally invasive surgery for the treatment of Mason II radial head fractures [21]. Metaizeau [22] and others first proposed the minimally invasive treatment of elastic titanium nail intramedullary fixation as the surgical choice for the treatment of radial neck fractures in children. This study pointed out that elastic titanium nail fixation technology has good rotational stability, the inserting and removing elastic titanium nail procedure is very simple, and this technology has the advantages of being minimally invasive with a short operation time and a low incidence of complications [23]. The AO (Arbeitsgemeinschaft für Osteosynthesefragen) principle of fracture treatment should follow the principle of restoring the articular surface and rigid fixation. Open reduction needs to expose the surgical field of vision, where it is easy to damage the blood supply to the radial head and may lead to complications such as ischemic necrosis, infection, heterotopic ossification, and joint stiffness of the radial head. The internal fixation should be strictly placed outside the "safe area"; otherwise, it can easily lead to internal fixation failure [24-26]. However, minimally invasive treatment far from the fracture site can perfectly avoid the occurrence of the above situation. The application of elastic titanium nail intramedullary fixation cannot damage the surrounding soft tissue of the fracture site, and it ensures that the blood supply of the fracture site is not damaged. After the fracture reduction, stability is achieved under the push of the surrounding healthy soft tissue and the support of the elastic titanium nail, which has been called a "soft tissue splint" by Gao [16]. Under the premise of stabilizing the fracture, the additional trauma caused by the operation can be reduced as much as possible. When the stability of the elbow allows, early active rehabilitation exercises can also greatly avoid joint stiffness [7].

Elastic titanium nail intramedullary fixation using minimally invasive treatment technology combines many advantages to ensure the safety of the operation. It has several beneficial characteristics, including a small incision, a short operation time, a fast healing speed, and low cost. However, if only a single elastic titanium nail is used for fixation, the operation may fail. This is because a single elastic titanium nail may have the disadvantages of insufficient holding force and limited anti-rotation ability, so it is unable to maintain the three-dimensional stability of the fracture site.

Given this, our team summarized and proposed an innovative technology using minimally invasive treatment for Mason type II radial head fractures with two elastic titanium nails. Our results indicated excellent clinical treatment outcomes. Compared with single elastic titanium nail fixation, our experience was as follows: (1) Due to the large medullary cavity of the adult radius, a single nail may have insufficient holding force and lead to fixation failure; (2) Double elastic titanium nails have good elastic recovery, and they are buried under the cartilage to form a triangular thrust and pressure; this was conducive to the reduction of the fracture site and provided anti-bending strength of the fracture site, and (3) The volume effect of two elastic titanium nails improved the fixation stability, resulting in better support that was enough to resist the compression of the fracture site and allow for stronger anti-rotation stress. Until now, there have been no studies on the treatment of radial head fractures with two elastic titanium nails.

However, the double elastic titanium nail intramedullary fixation technology presented here also has its own shortcomings. First, this study was only used for Mason type II fractures. Compared with more complex type III and IV fractures, we recommend open reduction and internal fixation. This is because the large and small fracture fragments make the elastic titanium nails an unsuitable approach. Furthermore, this technique is not suitable for patients with medullary stenosis who cannot pass through the thinnest elastic titanium nail and/or have severe osteoporosis. In addition, we have not conducted a thorough biomechanical study of this technique. Due to the lack of case numbers and experimental controls, the true advantages of this technique remain uncertain. Moreover, the experiment's follow-up times did not allow for an evaluation of the long-term efficacy. There are also some limitations, which will need to be confirmed by completing follow-up studies.

Conclusions

The minimally invasive treatment of Mason type II radial head fractures with double elastic titanium nails has several advantages, including a short operation time, a small incision, less additional injury as a result of the operation, fewer complications, satisfactory elbow function recovery, and satisfactory clinical effectiveness. Therefore, this novel and effective approach is worthy of further study and wider clinical use.

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Disclosure of conflict of interest

None.

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