

Comparative Study Between the Mini-Open (≤ 2.5 Cm) Approach and Conventional Open Lateral Approach in the Surgical Treatment of Radial Head Fractures

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Purpose: The conventional lateral approach is widely used to treat radial head fractures with screws. However, the traditional incision may have shortcomings, including excessive exposure and significant scarring. We propose an innovative method – a mini-open lateral approach of less than 2.5 cm for surgical treatment of radial head fractures with screws.

Methods: From Jan 2017 to Dec 2020, 34 patients diagnosed with closed radial head fracture were treated with open reduction and internal fixation (ORIF) in this study. The novel group (mini-open group) included 15 patients, and the other 19 patients were in the traditional group. The time of operation and the blood loss during operation were recorded. Postoperative clinical outcomes and radiographic results were recorded and compared between the two groups. The range of motion (ROM) in the elbow, the Visual Analogue Scale (VAS), the Mayo Elbow Performance Score (MEPS), Rating Scale of the American Shoulder and Elbow Surgeons (ASES), and the Shortened Disabilities of the Arm, Shoulder and Hand Questionnaire (Q-DASH) score and complications, such as wound infection, vascular and nerve damage, and fragment redisplacement were observed in the two groups.

Results: In the comparison between the two groups, there was no significant difference in age, sex, cause of radial head fracture, or other basic information. The operation time, intraoperative blood loss, and VAS score at 3 days postoperation were significantly reduced in the novel group ($p < 0.05$). The follow-up results showed that there was no significant difference in MEPS, ASES, or Q-DASH scores between the two groups.

Conclusion: The mini-open approach reduced intraoperative blood loss, shortened operation time, relieved patient pain, and achieved a satisfactory postoperative clinical result, which demonstrates that the novel approach is a safe and effective option for treating radial head fractures.

Keywords: radial head, mini-open, fracture, screw, clinical efficacy

Introduction

Radial head fracture is one of the most common injuries in the human body, accounting for one-third of all elbow fractures.^{1–3} Mason first reported radial head fractures and proposed the initial classification in 1945,³ which was modified in 1986.⁴ It is well evidenced that radial head fractures with a nondisplacement of < 2 mm (type I) can be treated nonoperatively with good results. Open reduction and internal fixation (ORIF) is the most common treatment choice for radial fractures.⁵

Commonly used internal fixations include screws, plates, Kirschner wires, and biodegradable screws.⁶ A previous study reported that K-wire cannot compress the fracture line, which may result in migration of the fracture.⁷ The plate is

usually considered to be bulky and leads to annular ligament injury.⁸ Screws are the most commonly used fixation because of the advantages of less damage to soft tissue and firm fixation.⁹

Interest in the minimally invasive surgical treatment of radial head fracture in this context seems to have increased in the literature. Many scholars have argued that minimally invasive surgery significantly reduces blood loss and shortens operative time.^{10–12} Gao et al reported a minimally invasive method of closed reduction using titanium elastic nails.¹³ Jia et al also studied this method and improved it.¹⁴ Wang et al described the excellent result of arthroscopic fixation using Kirschner wires.¹⁵ Hence, the best surgical method for the treatment of radial head fractures remains controversial.

Traditionally, ORIF using screws requires an incision from the lateral epicondyle to the proximal part of the radius along the mid axial line.^{5,16} This method is suitable for all types of radial head fractures. However, the traditional incision may have some shortcomings, including excessive exposure and significant scarring. It could cause additional pain and psychological burden to the patient.^{17–20} Therefore, we propose an innovative method - a mini-open lateral approach of less than 2.5 cm for surgical treatment of radial head fractures with screws. The purposes of this study are to (1) offer an idea that radial head fracture can be exposed through a minimally invasive approach based on the Kocher approach or the Kaplan approach; (2) demonstrate that this approach supports anatomical reduction under direct vision and results in fewer complications related to surgery; and (3) describe the operation methods and the clinical utility of this approach and evaluate the safety, efficacy, and benefits through radiographic, clinical, and functional outcome data on patients with radial head fractures.

Materials and Methods

Inclusion and Exclusion Criteria

The inclusion criteria in this retrospective study were as follows: (i) patients diagnosed with fracture of the radial head by X-ray; (ii) patients who underwent ORIF with screws; (iii) patients with a follow-up of more than 6 months.

The exclusion criteria were as follows: (i) patients younger than 16 years. (ii) any other injuries around the elbow except fracture of the radial head; (iii) time from injury to operation of more than 3 weeks; (iv) open fracture; (v) mason type I or non-operation (Figure 1)

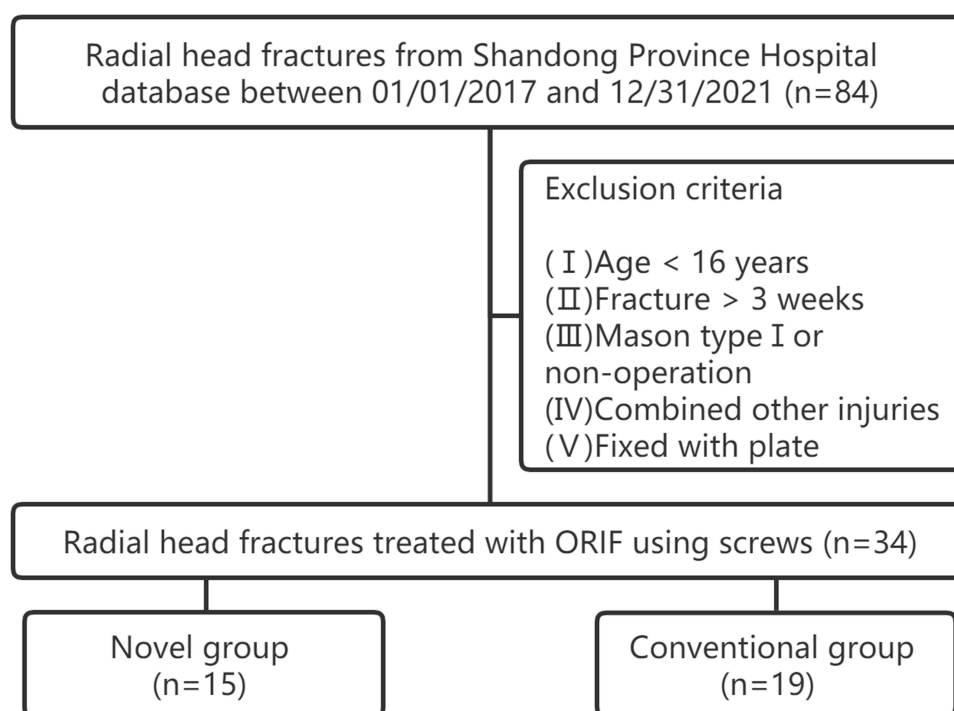


Figure 1 Exclusion criteria.

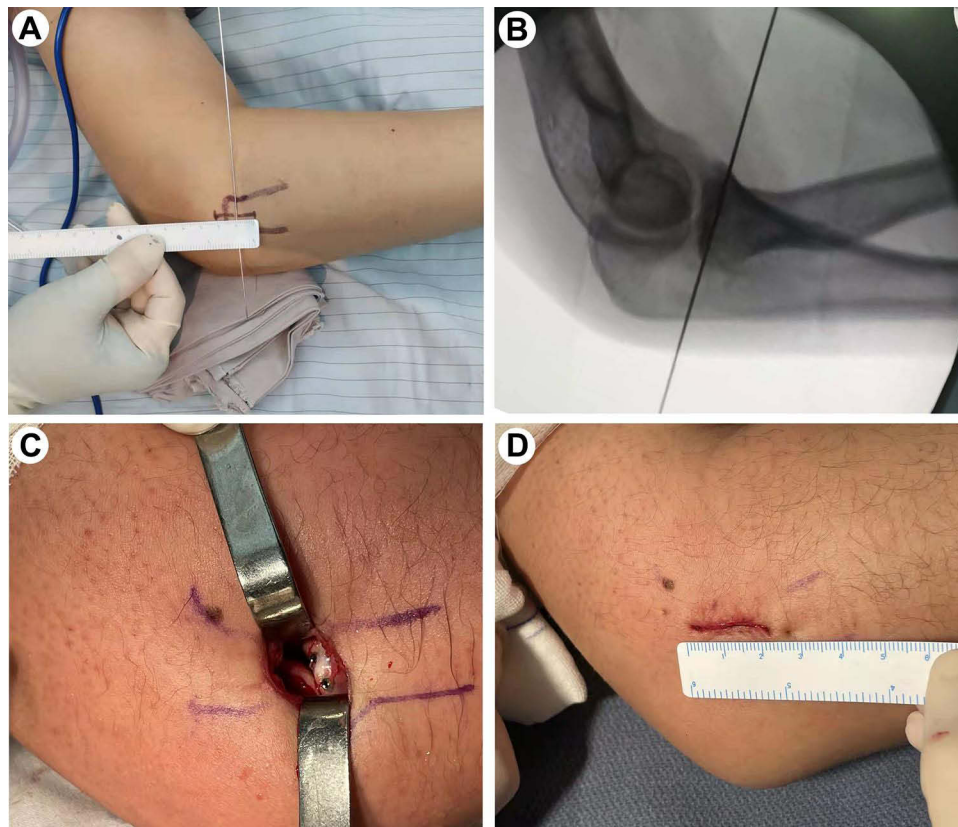


Figure 2 Surgical technique applied to a 27-year-old male patient with Mason type II fracture. (A) Mark of the incision location preoperation; (B) Preoperative fluoroscopy to locate the incision; (C) Exposure of the fracture region and insertion of the screws; (D) Photo of incision postoperation.

Surgical Technique

Patients were placed in the supine position with their injured limb in 90° of abduction and elbow joint in 90° flexion. The location of the radial head was determined according to the body-surface markers and drawn with a marker pen (Figure 2A). A Kirschner wire was placed parallel to the brachioradialis joint on the lateral side to confirm its placement using fluoroscopy (Figure 2B). A vertical line of approximately 2.5 cm was made across the k-wire, which was the surgical incision. The radial long carpal extensor and radial short carpal extensor muscles were visible anteriorly in the incision, and the elbow muscles were visible posteriorly after separating the subcutaneous tissue. The deep radial nerve branch was kept away from the operative field by rotating the forearm forward. The joint capsule was incised along the incision to create a precise exposure of the fracture. Reduction of the fracture was performed by leveraging the K-wire and probe. Screws were inserted into the radial head after satisfactory reduction (Figure 2C). The incision is approximately 2.5 cm in length (Figure 2D). Different screw fixation methods were used for the fixation of different types of fractures (Figure 3). A K-wire was used to predrill a hole to prevent the bone block from breaking before drilling the screws. The screw can be replaced by a K-wire when the bone mass is quite small. For Mason III fractures with two large and stable bone masses, screws are used to turn two bone blocks into one. X-ray imaging was used to verify fracture fixation refinement.

Postoperative Management

All patients were bandaged with light dressings after operation. Ice compressions were applied for swelling at least 2 days. All patients were given non-steroidal anti-inflammatory and analgesic drugs (NSAIDs) to relieve acute pain and prevent heterotopic ossification (HO).²¹ Each of them was encouraged to perform passive flexion, extension, and rotation exercises on the injured limb 1 day after surgery, with no restrictions on the rest of the limbs. Active functional exercise was started at 3 weeks, and unrestricted activity was observed after fracture healing at 3 months after surgery. The first

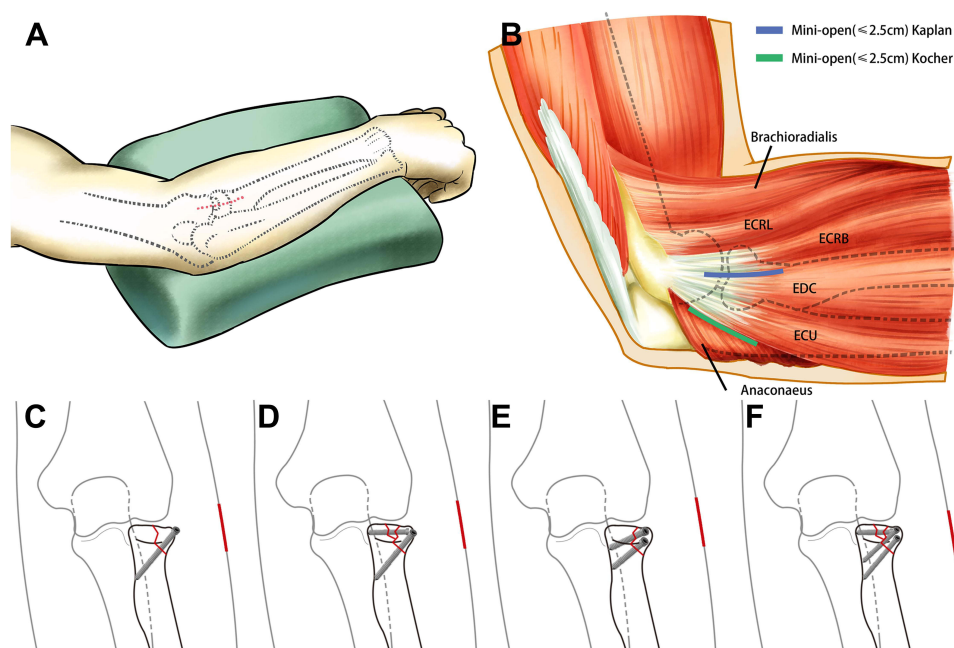


Figure 3 Different screw fixation methods were used for fixation of different types of fractures. **(A)** Schematic diagram of intraoperative posture and mini-open incision. **(B)** Two main surgical approaches in our study: mini-open Kocher approach and mini-open Kaplan approach. **(C)** Single screw only for Mason type II fractures and the fracture block is small. **(D)** Two screws are required when the bone is large. **(E)** When a Mason type III fracture has two small fracture blocks, the first screw is used to fix two small blocks into one piece, and the other is used to fix the block to the radial head. **(F)** When a Mason type III fracture has two fracture blocks, one of which is larger, the first screw is used to fix the two blocks into one piece, and the others are used to fix the block to the radial head.

follow-up was usually two weeks after discharge from the hospital and included only clinical evaluation. Radiographic evaluation was also performed after one and two months, unless any complications occurred sooner.

Evaluation Criteria of the Clinical Effectiveness

The interval between injury and surgery, operative time, blood loss, length of hospital stay, and operative complications were collected and reviewed. The Visual Analogue Scale (VAS) score at 3 days postoperation was used to evaluate the pain difference between the two groups. Patients were evaluated by the same surgeon at each of the follow-up visits, where the range of motion (ROM) in the elbow, the VAS, the Mayo Elbow Performance Score (MEPS), Rating Scale of the American Shoulder and Elbow Surgeons (ASES), and the Shortened Disabilities of the Arm, Shoulder and Hand Questionnaire (Q-DASH) score were recorded.

Statistical Analysis

All results were evaluated using SPSS 25.0 for Windows (IBM, USA). Differences in patient characteristics between the two approaches, such as sex, mechanism of injury, and fracture classification, were compared along with clinical and radiographic outcomes using Fisher's exact test. Patient age, blood loss, and surgery time were compared using Student's *t* test. Complications were assessed using Fisher's exact test, including the rates of nerve injury, stiff elbow, and fracture nonunion. A *p* value of less than 0.05 was considered significant.

Results

From Jan 2017 to Dec 2020, a total of 34 patients with closed radial head fractures underwent ORIF using screws in our department. The mechanisms of injury were fall injuries in 31 cases, and traffic accidents in 3 cases. The demographics of the patients in the two groups are shown in Table 1. All patients were followed up for at least 1 year without death or loss to follow-up. The mean age of patients was 30.13 years (range 16 to 55 years) in the novel group, with a male/female ratio of 9:6. The mean age of patients was 30.79 years (range 19 to 48 years) in the conventional group, with a similar male/female ratio as the novel group. The mini-open approach was used in 15 patients, and the traditional lateral

Table 1 Demographics of Patients Between the Two Groups

	Novel Group	Conventional Group	p-value
Number of cases	15	19	
Gender (male/female)	9/6	13/6	0.724
Mean age, years (range)	30.13 (16–55)	30.79 (19–48)	0.844
Standard deviation (SD)	11.53	7.67	
Mechanism of injury			
Traffic accident	1	2	0.570
Fall	14	17	
Fracture type (Mason Classification)			
II	11	11	0.476
III	4	8	

approach was used in 19 patients. The mini-open population was composed of 11 Mason II and 4 Mason III fractures, while the traditional population was composed of 11 Mason II and 8 Mason III fractures. There were no significant differences between the two groups in terms of mean age, gender composition, or type of fracture between the two surgical approaches.

Operative Records

The operative time for the novel group was 66.20 ± 11.74 min, with intraoperative blood loss of 18.70 ± 11.25 mL. The operative time for the conventional group was 87.58 ± 32.02 min, with intraoperative blood loss of 35.79 ± 17.10 mL. There were significant differences in blood loss ($p = 0.002$) and operative time ($p = 0.020$) between the approaches. The hospital stays were 5.13 ± 1.60 days in the novel group and 6.26 ± 2.13 days in the conventional group, with no significant difference ($p > 0.05$). The VAS score at 3 days postoperation was 3.20 ± 0.68 in the novel group and 3.89 ± 9.34 in the conventional group ($p = 0.022$; Table 2).

Functional Assessment

The mean elbow ROM for the novel group was $139.50^\circ \pm 3.44$ for flexion-extension, $86.87^\circ \pm 3.11$ for pronation, and $86.47^\circ \pm 3.13$ for supination, whereas the mean ROM for the conventional group was $139.53^\circ \pm 3.36$ for flexion-extension, $87.05^\circ \pm 2.68$ for pronation, and $87.37^\circ \pm 2.65$ for supination (Figure 4).

The mean MEPS scores were 96.33 ± 3.99 points in the novel group and 93.68 ± 5.74 points in the conventional group ($p = 0.138$). The mean ASES scores were 13.80 ± 0.41 in the novel group and 13.89 ± 0.32 points in the conventional group ($p = 0.454$). The mean Q-DASH scores were 0.60 ± 1.40 points in the novel group and 0.84 ± 1.95 points in the conventional group ($p = 0.689$). Comparing the ROM, ASES, MEPS, and Q-DASH scores between the two groups, no significant differences were observed (Table 3).

Table 2 The Operative Records and Statistical Analysis Between the Two Groups

	Novel Group	Conventional Group	p-value
Interval between injury and surgery [d]	4.67 ± 1.95	5.11 ± 4.00	0.700
Blood loss [mL]	18.70 ± 11.25	35.79 ± 17.10	0.002**
Hospital stays [d]	5.13 ± 1.60	6.26 ± 2.13	0.097
Operation time [min]	66.20 ± 11.74	87.58 ± 32.02	0.020*
VAS at 3 days postoperation	3.20 ± 0.68	3.89 ± 9.34	0.022*

Notes: * $p < 0.05$, ** $p < 0.01$.

Abbreviation: VAS, the visual analogue scale.

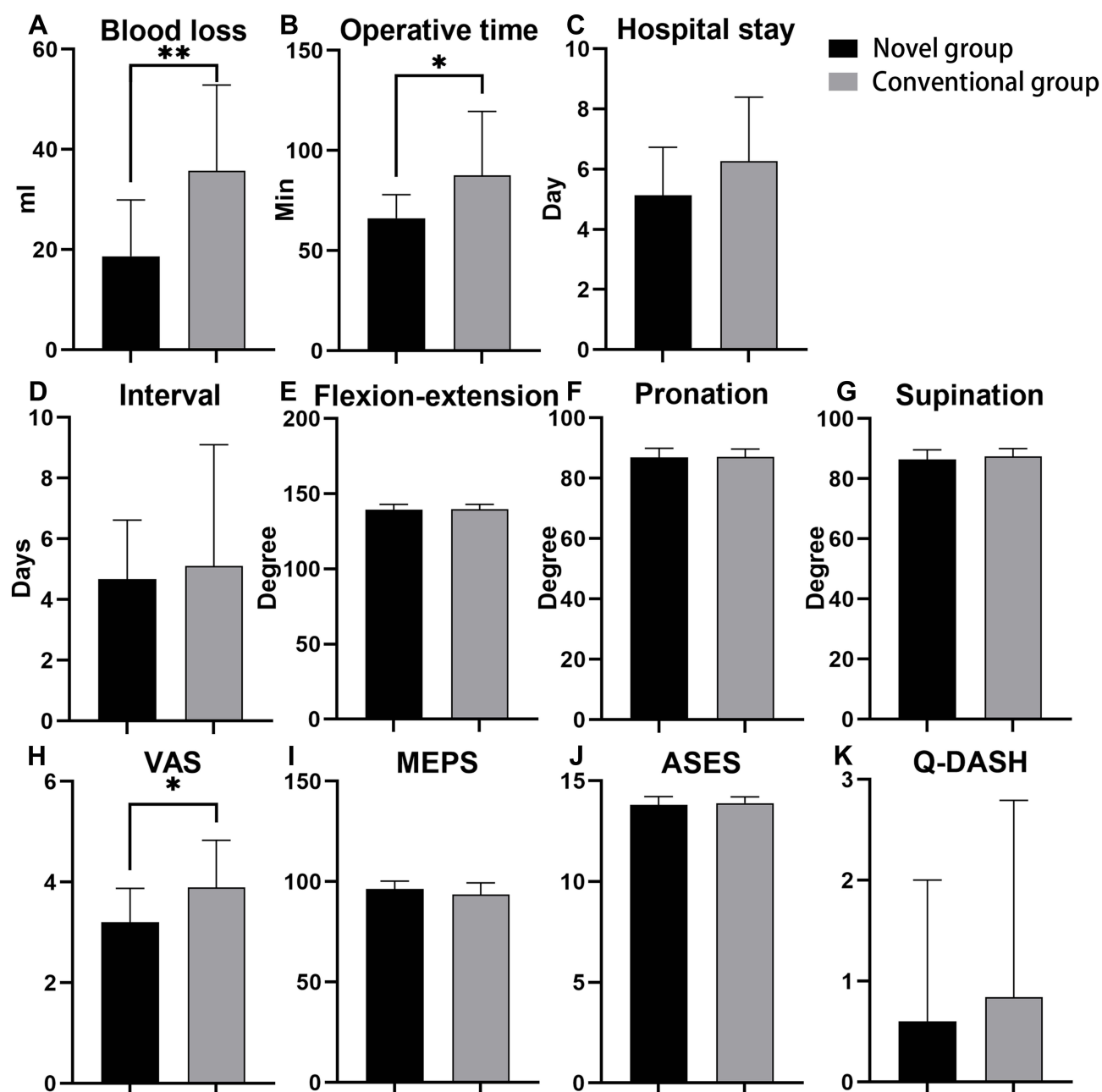


Figure 4 The comparison between novel group and conventional group. (A) Blood loss in operation; (B) Operative time; (C) Hospital stay; (D) Interval between injury and surgery; (E-G) ROM of elbow; (H) VAS score; (I) MEPS score; (J) ASES score; (K) Q-DASH score.

Notes: * $p<0.05$, ** $p<0.01$.

Abbreviations: VAS, the visual analogue scale; ROM, the range of motion; MEPS, the Mayo Elbow Performance Score; ASES, the rating scale of the American shoulder and elbow surgeons; Q-DASH, the shortened disabilities of the arm, shoulder and hand questionnaire.

Complications

All surgical incisions healed without complications, such as wound infection, vascular damage, nerve damage, and fragment redisplacement, and all patients had radiographic union at the 3-month follow-up. Only 2 patients underwent removal of the internal fixation at 12 and 14 months postoperatively, and the remaining patients did not undergo secondary surgery. All patients achieved good clinical and radiological results, with no nonunion or delayed fracture healing and no elbow pain, joint stiffness, heterotopic ossification, or posttraumatic arthritis until the last follow-up (Figure 5).

Table 3 The ROM and Clinical Scores at 6 Months Postoperation

	Novel Group	Conventional Group	p-value
Follow up[months]	19.33 ± 5.16	20.47 ± 7.01	0.602
Flexion-extension[°]	139.50 ± 3.44	139.53 ± 3.36	0.915
Pronation[°]	86.87 ± 3.11	87.05 ± 2.68	0.853
Supination[°]	86.47 ± 3.13	87.37 ± 2.65	0.370
ASES	13.80 ± 0.41	13.89 ± 0.32	0.454
MEPS	96.33 ± 3.99	93.68 ± 5.74	0.138
Q-DASH	0.60 ± 1.40	0.84 ± 1.95	0.689

Abbreviations: ROM, the range of motion; MEPS, the Mayo Elbow Performance Score; ASES, the rating scale of the American shoulder and elbow surgeons; Q-DASH, the shortened disabilities of the arm, shoulder and hand questionnaire.

Discussion

Compared with the traditional lateral approach, the mini-open approach for radius fractures can significantly reduce intraoperative bleeding, shorten the operative time, and relieve patient pain, with satisfactory postoperative function.

At present, ORIF has been recommended for radial head fractures above Mason type II.^{22–24} For this type of fracture, the conventional surgical approaches include the Kocher approach and the Kaplan approach.²⁵ The advantage of those approaches is reduction under direct vision, which can achieve a complete anatomical reduction of the radial head and maximize the restoration of elbow joint function. Anatomical reduction of fracture is critical for optimal long-term outcomes and prevention of postoperative complications.²⁶ However, there are several disadvantages to those approaches, including possible excessive tissue damage. Both approaches require a sizeable lateral incision, which leads to excessive damage and reduces the blood supply to the fracture site. It can also result in tissue damage and intraarticular haematoma formation, which increases the risk of elbow stiffness, heterotopic ossification, nerve injury, and other complications.²⁷

The plate and the screw are commonly used in the treatment of radius fractures. T. C. Koslowsky et al compared four different fixations for Mason type III fractures in a cadaver study of 96 cases and found that the Fragment Fixation

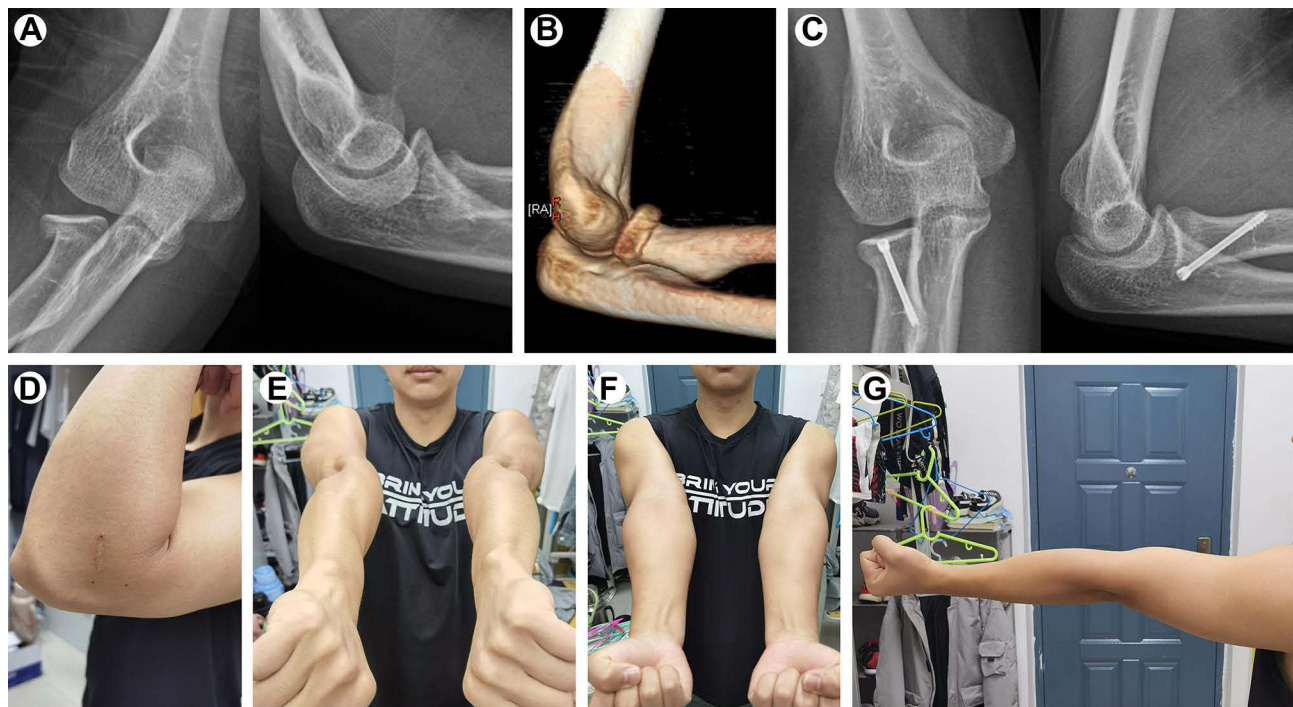


Figure 5 Male, 23 years with fracture type II who underwent ORIF by novel approach: (A and B): X-ray and 3D-CT images after injury showing a Mason type II fracture; (C): X-ray at 6 months postoperation showing healing of the fracture; (D-G): The ROM of shoulder at 6 months postoperation.

System (FFS) provided a better quality of reduction than others and that there was significantly better stability when using FFS implants, mini-screws, and K-wires than when using mini plates.²⁸ A similar test was performed in cadavers and indicated that cross-cannulated screws were superior to conventional T-plates.²⁹ Another study demonstrated that the stiffness of the screw and plate are similar in all planes, even though the stiffness of the screw was 1.8 times that of the plate from medial to lateral.³⁰ Iacobellis C et al described good results in a clinical study treated by screws alone and suggested that screws are less invasive and can be used alone to treat Mason type II and III fractures of the radial head, especially for Herbert screws, which can be completely buried in the bone.³¹ Thus, screws for internal fixation of the radial head fracture can greatly replace conventional plates.⁵

The surgical treatment for radial head fracture tends to be minimally invasive.³² The minimally invasive concept was first applied to the proximal radius by Metaizeau et al in 1980. He suggested that elastic stable intramedullary nail fixation (ESIN) can be used for radial neck fractures in children.³³ Sandmann et al proposed this method as a suitable and reliable choice for radial neck fractures in adults.³⁴ Gao et al reported good outcomes in Mason type II radial head fractures studied via intramedullary pinning.¹³ Jia et al improved this technology to double elastic titanium nails and achieved excellent clinical effectiveness.¹⁴

Given the above, we proposed a novel approach based on conventional methods for Mason type II and III radial head fractures with crossed screws. No significant differences were found in the function of the elbow between the two approaches in our study, which indicates that our approach provides an adequate view to expose the fracture site, allowing accurate reduction of the radial head facet and convenient placement of the screws to achieve rigid fixation, although the incision is approximately 2.5 cm in length. There are several advantages to our new approach. First, our incision does not need to cross the elbow joint, which may alleviate pain when the patient performs rehabilitation exercises before the wound heals. In our study, there was a significant difference in the VAS score at 3 days postoperatively between the two groups. Second, our approach can reduce intraoperative blood loss and decrease operative time substantially. There were significant differences in blood loss and operative time between the two groups. However, it should be noted that the blood loss of these two incisions may have little effect on the human body. Finally, the scar of our novel approach is smaller, resulting in long-term cosmetic improvement that is particularly beneficial for patients with specific cosmetic requirements.

Postoperative pain may affect patients' motivation to engage in rehabilitation exercises.^{35,36} Meanwhile, pain intensity is aggravated by rehabilitation, which may limit the patient's participation.³⁷ A previous study have shown that lack of rehabilitation is an independent risk factor for stiff elbow.³⁸ Ranawat et al have emphasized that pain is an important factor to consider throughout the rehabilitation process.³⁹ Vincent et al also proposed that joint pain can affect physical functions and reduce the quality-of-life.⁴⁰ In our study, the VAS score of the mini-open incision group was significantly lower than that of the controls, it may be beneficial for early rehabilitation exercise.

In the treatment of radial head fracture with a novel small incision, our experience was as follows: (1) This method is only applicable to mason type II and type III fractures with few fracture fragments and small displacement. It should also not be used in patients with radial head fractures with ligament injuries, such as lateral collateral ligament (LUCL) injuries. (2) The deep branch of the radial nerve should be kept away from the operative site by rotating the forearm anteriorly to reduce the chance of injury. (3) When the fracture fragment is posterior, a gap between the anconeus and the extensor carpi ulnaris (ECU), as is used with the Kocher approach, should be used to expose the radial head. When the fracture fragment is anterior, a gap between the extensor digitorum communis (EDC) and the extensor carpi radialis brevis (ECRB), as is used in the Kaplan approach, should be used.⁴¹ (4) If the patient's radial head is not easy to recognize, the C-arm X-ray machine can help localize the incision accurately.

There are still some limitations to this study. First, our study was retrospective rather than prospective. Our analysis was conducted on a small number of patients. Future multicentre, large sample and adequately powered randomized controlled trials are needed to assess the efficacy of these interventions. In addition, the lack of postoperative CT data in some patients is another limitation. Moreover, follow-up of long-term functional outcomes is missing and is expected to improve after 3 years. Finally, the possibility of further reduction of the incision remains to be investigated intensely.

Conclusion

The mini-open approach reduced intraoperative blood loss, shortened operation time, relieved patient pain, and achieved a satisfactory postoperative clinical result, which demonstrates that the novel approach is a safe and effective option for treating radial head fractures.

Data Sharing Statement

All data generated or analysed during this study are included in this published article.

Ethical Statement and Informed Consent

The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University. Written informed consent was obtained from each study participant. The typical case in this study provided written informed consent for this image to be published.

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Disclosure

The authors report no conflicts of interest in this work.

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