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Elastic stable intramedullary nails compared to locking compression plates for treating unstable distal ulnar fractures in adults: a prospective comparative study

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Abstract

Background and purpose Distal ulna fractures often occur in conjunction with distal radius fractures and other associated injuries. Currently, there are no satisfactory internal fixation systems available for addressing unstable distal ulna fractures, and a definitive consensus on the most effective treatment approach is still lacking. The objective of this research was to evaluate the clinical outcomes of using elastic stable intramedullary nails (ESIN) compared to locking compression plates (LCP) for treating unstable distal ulnar fractures in adults.

Methods In a prospective clinical study, a total of 54 patients (21 females and 33 males; average age 49.3 years, ranging from 30 to 63 years) suffering from unstable or displaced fractures of the distal ulna were randomly allocated to one of two treatment groups between January 2021 and August 2024. Specifically, 26 patients underwent treatment utilizing elastic stable intramedullary nails, whereas 28 patients were managed using locking compression plates. The two groups were evaluated prospectively for perioperative data and functional results.

Results The ESIN group comprised 26 patients, exhibiting a mean age of 48.27 years (with a range of 30 to 62 years), while the LCP group included 28 patients, whose mean age was 50.33 years (ranging from 32 to 63 years). Both groups were comparable regarding gender distribution, side of injury, mechanisms of injury, and classifications of fractures. However, there were significant differences noted in incision length of the ulna, surgical duration, frequency of fluoroscopy, and the rates of excellent and good functional outcomes as measured by the Gartland-Werley scores between the two groups ($P < 0.05$). Conversely, no significant differences were found concerning the time to union and the duration of immobilization between the two groups ($P > 0.05$).

Conclusion ESIN offers several advantages, including reduced incision length, lower frequency of fluoroscopy, shorter duration of the surgical procedure, decreased complication rates, and improved Gartland-Werly scores. Therefore, fixation using ESIN serves as an effective alternative for the treatment of distal ulnar fractures in adults. The minimally invasive nature and lower complication rates are defining characteristics of ESIN fixation.

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Keywords Distal ulna fracture, Elastic stable intramedullary nail, Locking compression plate, Open reduction and internal fixation

Introduction

The bony structure of the distal ulna comprises the ulnar styloid process, the ulnar head, and the distal portion of the ulnar metaphysis. Acting as a stable pivot, the distal ulna facilitates the rotation of the radius, thereby assisting in the movement of the forearm [1]. The dome and seat make up the ulnar head, with the dome facing the carpus and the seat connecting with the radius at the sigmoid notch, which is covered by about 130° of articular cartilage [2]. The ulnar head functions as an essential keystone within the architecture of the distal radioulnar joint (DRUJ) and the sigmoid notch located on the distal radius. Therefore, improper management of a distal ulnar fracture may lead to multiple complications, such as restrictions in forearm rotation, ongoing ulnar-sided wrist discomfort, and instability of the DRUJ [3–5]. The fovea located on the ulnar head functions as the primary axis for the rotation of the ulnar head and serves as the connection site for the deeper parts of both the dorsal and palmar radioulnar ligaments [6]. Meanwhile, the ulnar styloid is a bony prominence at the distal end of the ulna, which acts as the anchorage for the superficial component of the dorsal ligaments and the distal radioulnar joint (DRUJ).

Biomechanical forces exerted on the wrist generate varying loads at the ulnocarpal joint, influenced by the wrist's rotational positions and grip [7]. In a neutral alignment, the ulnocarpal joint bears approximately 20% of the weight distributed across the wrist. Additionally, there are relative increases in both the length of the ulna and the loading during gripping actions or when the forearm rotates into pronation [8].

Fractures of the isolated distal ulna are considered relatively infrequent [9]. However, these fractures are commonly observed in older adults and often occur in conjunction with fractures of the distal radius [10]. In patients with unstable distal radius fractures, as many as 6% of the unstable metaphyseal fractures may be diagnosed [11]. Compared to distal radius fractures, the significance of distal ulna fractures is frequently underestimated, and their management remains a topic of ongoing debate. The distal ulna interacts complexly with both the lower radioulnar joint and the triangular fibrocartilage complex, which complicates the treatment process due to factors such as osteoporosis, limited soft tissue coverage, and a restricted area for fixation [12, 13].

Numerous distal ulna fractures are considered stable following the reduction and stabilization of associated distal radius fractures, often resulting in favorable outcomes with non-surgical management [14–16]. This is particularly true for older patients, for whom conservative treatment using plaster casts is common due to compromised bone quality and the frequent complications associated with traditional osteosynthesis techniques. However, conservative management can lead to well-documented issues, such as prolonged periods of immobilization, which may result in muscle atrophy and joint stiffness, ultimately hindering individuals' ability to resume their previous activities. Evidence indicates that non-operative interventions can yield suboptimal results in cases of displaced or unstable ulna fractures [17, 18]. Currently, various fixation techniques are available for addressing unstable distal ulna fractures [19–22]. Nonetheless, persistent challenges remain, including hardware irritation, insufficient fixation strength, and complications arising from flexible internal fixation or ruptures [23, 24]. As a result, a definitive consensus on the most effective treatment approach is still lacking.

To reduce complication rates and enhance clinical effectiveness, we employed elastic stable intramedullary nailing (ESIN) for the fixation of distal ulna fractures. We hypothesized that ESIN fixation, in contrast to locking compression plate (LCP) fixation, not only facilitates minimally invasive reduction and may decrease the likelihood of bone nonunion following extensive dissection of incisions and periosteum, but also offers several intrinsic advantages. This study aims to prospectively evaluate the functional and radiographic outcomes, as well as the complications associated with ESIN fixation compared to LCP fixation in adult patients with distal ulna fractures.

Patients and methods

Approval for this prospective study was obtained from the Institutional Review Board of the authors, along with informed consent from all participants. The findings have been presented in accordance with the STROCSS guidelines [25]. Between January 2021 and August 2024, a total of 54 individuals, with an average age of 49.3 years (ranging from 30 to 63 years), sustained distal ulna fractures and were randomly assigned to receive either elastic stable intramedullary nail (ESIN) fixation constructs (ESIN group) or locking compression plate (LCP) constructs (LCP group). This assignment was based on block randomization considering age, sex, and fracture type, utilizing a computer-generated random number sequence. To uphold the integrity of the randomization process, the grouping information is sealed in opaque envelopes, ensuring that both researchers and patients remain unaware of the group assignments prior to the grouping. The generation of random number sequences, as well

as the preparation and preservation of the envelopes, is managed by researchers not involved in patient recruitment, treatment, or grouping. Surgical procedures were performed by a team of five trauma specialists. The inclusion criteria were as follows: (1) after an attempt at closed reduction of a distal ulna fracture or surgical intervention for a simultaneous distal radius fracture, malalignment of the distal ulna fracture persisted at ≥10 degrees; (2) an observed change in ulnar variance of 3 mm or ≥1/3 translation of the fracture surface; (3) noticeable movement between fracture fragments during passive forearm rotation, associated with dislocation of the distal radioulnar joint or ≥50% distal ulnar subluxation relative to the distal radius [26–28]. The exclusion criteria included: (1) patients under 18 years of age; (2) cases involving neuromuscular paralysis or injuries to the central nervous system; (3) classification of the Q modifier type as Q1, Q4, or Q5 for distal ulnar fractures.

Demographics and perioperative data

Demographic information of patients, mechanisms underlying their injuries, classifications of fractures, and fixation techniques were documented. During subsequent follow-ups, we evaluated complication rates, the duration required for fracture union, and the final range of motion. Additionally, as part of the perioperative data, we recorded the length of the ulna incision, the interval prior to surgery, the duration of the surgical procedure, the number of fluoroscopy sessions, and the postoperative immobilization period.

Operative technique

The operative technique was done under brachial plexus nerve block. Fracture fixation was performed under tourniquet control, reduction and internal fixation of concurrent distal radius fractures was undertaken firstly. All plates and ESIN were from Waston Medical, Changzhou, China.

In the LCP constructs, access to the distal radius was achieved through either the radial flexor carpal approach or the distal radius-dorsal approach. Distal radius fractures are typically stabilized using palmar or dorsal anatomical locking plates. In cases involving a compressive fracture of the articular surface or fractures of the radial styloid, additional interventions such as bone grafting and the application of Kirschner pins or screws are necessary for adequate stabilization. Once the radius fracture has been appropriately managed, radiographs are obtained to assess whether further management of a distal ulnar fracture is required to meet the inclusion criteria. Open reduction and internal fixation of the distal ulna were performed using a direct approach to the subcutaneous distal ulna. Reduction was achieved and provisionally stabilized, with X-ray imaging employed to confirm the rotational alignment and reduction of both fractures. The fixation of the implants was then secured definitively. For simple fractures, a conventional screw can be employed in the sliding hole to apply pressure to the fractured ends. For the remaining screw holes, the use of locking screws is advisable. In the context of medical instrument availability in China, there are limited internal fixation options for distal ulnar fractures. In our case, the locking compression plate (LCP) utilized for the distal ulna fracture was a metacarpal bone plate. The length and number of screws were determined based on the fracture line and the severity of the fracture, with a minimum of three screws on each side of the fracture generally being ensured.

In the ESIN constructs, the distal ulnar fracture was stabilized using an anterograde ESIN. The insertion point was located on the dorsal radialis of the proximal ulna, approximately 3.0 cm from the tip of the olecranon. Following a 1.0 cm incision, a bone cone was employed to access the proximal medullary cavity of the ulna, after which an ESIN with appropriate diameter was inserted. Upon reaching the fracture site, the fracture was re-reduced through traction, guided by X-ray supervision. If this approach proved unsuccessful, a mini-open approach was utilized to expose the fracture site, thereby facilitating optimal reduction during the insertion of the ESIN. After achieving satisfactory fracture reduction and ensuring reliable fixation, the tail of the elastic intramedullary nail was trimmed. The diameter of the elastic intramedullary nail is determined by the size of the ulnar bone marrow cavity, and preoperative X-ray results can provide guidance for selecting an appropriate size. In our cases, intramedullary nails with diameters ranging from 3.0 to 4.0 mm are generally selected.

Pain management was administered to both groups as needed. When the patient's Visual Analog Scale (VAS) pain score reached 4 or higher, we administered a 100 mg capsule of celecoxib twice daily for analgesia. Physiotherapy was initiated as soon as it was deemed feasible. Antibiotics were administered for 24 h post-surgery. The surgical incision was regularly cleaned and dressed, and the plaster cast was maintained for a duration of 3 to 5 weeks. Functional exercises for the finger, elbow, and shoulder joints commenced 24 h after the procedure. The affected limb was elevated, and a cold compress was applied to the operative area to mitigate swelling. The timing of plaster removal and the follow-up rehabilitation plan were determined based on the results of reexamination. Follow-up evaluations were conducted at intervals of 1 month, 2 months, 3 months, 6 months, 1 year, 1.5 years and 2 years during which radiological assessments of bone healing and functional outcomes were performed.

Radiological evaluation

Radiographs of the wrist joint were obtained prior to the operation to classify all fractures according to the Q modifier classification for distal ulna fractures [10]. Instances of nonunion, malunion, and various other complications were documented. A union time frame exceeding three months is classified as 'delayed union', while a duration surpassing nine months, during which no signs of growth have been observed for three consecutive months, is categorized as 'non-union'. The presence of bridging callus on both anteroposterior (AP) and lateral radiographs was used to define radiographic union. To eliminate bias and ensure consistency in assessment levels, all radiological evaluations were conducted by the same senior physician in the orthopedic department, who was not involved in the study.

Clinical evaluation

At the last follow-up, functional outcomes were assessed using the Gartland-Werley scoring system [29]. This system provides a comprehensive evaluation of wrist function across four critical domains: residual deformity, subjective pain levels, wrist mobility, and complications, which encompass arthritic changes, neurological issues, and problems related to casting. The scoring is categorized into four classifications: excellent (0–2 points), good (3–8 points), fair (9–20 points), and poor (≥ 21 points).

Complications evaluation

Complications were categorized into two groups: "minor," which resolve with observation or minimal intervention, and "major," which require a return to the operating room or result in significant long-term consequences [30, 31].

Statistical analysis

All continuous variables were analyzed using the two-sample t-test. The variables examined included age, length of incision, duration of the surgical procedure, time until surgery, frequency of fluoroscopy, length of postoperative immobilization, and time required for bone union. For the analysis of categorical data, the Fisher exact probability test was employed, particularly for small sample sizes. The categorical variables assessed comprised gender, injury side, fracture type, mechanism of injury, functional outcomes, and both major and minor complications. Functional outcomes were statistically analyzed using rank sum tests. When missing data constitutes a small proportion of the total sample size, we delete the missing entries and utilize the complete dataset for analysis. Conversely, when the missing data represents a substantial percentage of the overall sample size, we employ the mean or median to impute the missing values. A *P*-value of less than 0.05 was considered statistically significant for all calculations. The analysis was conducted using the Statistical Package for Social Sciences (SPSS, version 19.0, Chicago, Illinois).

Results

Patient characteristics

A total of twenty-six patients underwent ESIN fixation, comprising 16 males and 10 females. In contrast, twenty-eight patients received LCP fixation, which included 17 males and 11 females. The mean age of patients in the ESIN group was 48.27 years (ranging from 30 to 62 years), while the average age in the LCP group was 50.33 years (ranging from 32 to 63 years). Within the ESIN group, 14 individuals sustained right-sided fractures, whereas 12 had left-sided fractures. In the LCP group, right-sided fractures were observed in 13 patients, and 15 patients experienced fractures on the left side. According to the Q modifier classification for distal ulna fractures, the ESIN group consisted of 14 individuals with Q2 fractures, 2 with Q3 fractures, and 10 with Q6 fractures. In comparison, the LCP group included 16 patients with Q2 fractures, 3 with Q3 fractures, and 9 with Q6 fractures. The predominant mechanism of injury for both cohorts was falling onto an outstretched hand, reported in 17 of the 26 individuals from the ESIN group and in 19 of the 28 patients from the LCP group. The demographic factors, including age, gender, side of injury, Q modifier classification, follow-up period, and mechanism of injury, were comparable across both groups ($P > 0.05$; see Table 1).

Perioperative data

The average time from injury to surgery was 2.37 days (range, 1–5 days) for the ESIN group and 2.42 days (range, 1–5 days) for the LCP group, with no significant difference observed between them. The mean duration of surgery was significantly shorter for the ESIN group at 25.74 min (range, 20–36 min) compared to the LCP group, which averaged 32.68 min (range, 25–50 min) ($P < 0.001$). The average incision length of the ulna was 2.05 cm (range, 1–4 cm) in the ESIN group and 5.54 cm (range, 4–8 cm) in the LCP group, indicating a significant difference between the two groups. Additionally, The mean times of intraoperative fluoroscopy was significantly more in the LCP group than in the ESIN group (7.27 vs. 4.32) ($P < 0.001$). The average duration of immobilization was similar between the two groups, with the ESIN group averaging 3.65 weeks (range, 2–4 weeks) and the LCP group averaging 3.58 weeks (range, 2–4 weeks) ($P > 0.05$; Table 2).

Radiographic and functional outcomes

No significant statistical difference was observed in the time required to achieve union between the ESIN group

Table 1 Comparison of the general characteristics of the two groups

General information	ESIN group (%)	LCP group (%)	Statistic	*P* value
	N = 26	*N* = 28		
Age (yr)	48.27 ± 13.75	50.33 ± 12.68	0.5728	0.5693
Gender			0.0039	0.9505
Male	16 (61.5)	17 (60.7)		
Female	10 (38.5)	11 (39.3)		
Side of injury			0.2967	0.586
left	12 (46.2)	15 (53.6)		
right	14 (53.8)	13 (46.4)		
Injury mechanism				
Fall damage	17 (65.4)	19 (67.9)	0.3144	0.855
Traffic accident	7 (26.9)	6 (21.4)		
Other causes	2 (7.7)	3 (10.7)		
Q modifier classification			0.3123	0.855
Q2	14 (53.8)	16 (57.1)		
Q3	2 (7.7)	3 (10.7)		
Q6	10 (38.5)	9 (32.1)		
Follow-up period (months)	15.2 ± 5.0	14.5 ± 5.1	0.5087	0.6131

*Continuous variables are shown as mean ± standard deviation, while categorical variables are expressed as n (%)

Table 2 Comparison of the perioperative data of the two groups

	ESIN group	LCP group	Statistic	*P* Value
Incision length of ulna (cm)	2.05 ± 1.12	5.54 ± 1.28	10.6278	< 0.001
Time to surgery (days)	2.37 ± 1.08	2.42 ± 1.12	0.1668	0.8682
Duration of surgery (mins)	25.74 ± 4.64	32.68 ± 3.85	5.9983	< 0.001
Times of fluoroscopy	7.27 ± 1.26	4.32 ± 1.45	7.9529	< 0.001
Duration of immobilization (weeks)	3.65 ± 1.47	3.58 ± 1.42	0.1780	0.8594

*Continuous variables are shown as mean ± standard deviation, while categorical variables are expressed as n (%)

Table 3 Functional outcomes, radiographic outcomes, and complications in the two groups

	ESIN group (%) *N* = 26	LCP group (%) *N* = 28	Statistic	*P* Value
Fracture union (weeks)	10.74 ± 1.52	10.56 ± 1.48	0.4408	0.6612
Range of Motion				
Flexion (degree)	60.4 ± 7.6	62.7 ± 9.7	0.9648	0.3391
Extension (degree)	63.2 ± 6.8	62.5 ± 7.2	0.3666	0.7154
Pronation (degree)	77.4 ± 12.6	76.8 ± 9.6	0.1977	0.8441
Supination (degree)	78.5 ± 10.4	75.3 ± 6.8	1.3477	0.1836
Functional outcomes			−1.461	0.144
Excellent	16 (61.5)	14 (50.0)		
Good	8 (30.8)	5 (17.9)		
Fair	2 (7.7)	6 (21.4)		
Poor	0 (0)	3 (10.7)		
Complications			5.405	0.0200
Major	1 (3.8)	3 (10.7)		
Minor	2 (7.7)	8 (28.6)		

*Continuous variables are shown as mean ± standard deviation, while categorical variables are expressed as n (%)

(10.74 weeks, ranging from 9 to 14 weeks) and the LCP group (10.56 weeks, ranging from 9 to 13 weeks), resulting in a *P*-value of 0.6612 (see Table 3). Our findings indicate that there was no significant difference in the range of motion of the wrist joint (flexion, extension, pronation, and supination) between the two groups ($P > 0.05$). Typical cases are illustrated in Figs. 1 and 2. At the latest follow-up, most patients in both groups exhibited satisfactory flexion, extension, pronation, and supination of the wrist joint (Fig. 3), the consent had been obtained from the patient for possible publication of the figures. According to the Gartland-Werley scoring system, the

Fig. 1 A 61-year-old male presented with a Q3 fracture of the left distal ulna in conjunction with a distal radius fracture resulting from a traffic accident. (**A**) Preoperative anteroposterior and lateral radiographs revealed fractures of both the distal ulna and distal radius, with the distal ulna fracture classified as Q3 type. Following the open reduction and internal fixation of the distal radius fracture, the distal ulna fracture exhibited over 10 degrees of malalignment and one-third translation of the fracture surface. (**B**) X-ray after surgery with cast. (**C**) One month postoperatively, radiographs indicated callus formation at the fracture site. (**D**) X-ray results confirmed clinical healing of the fracture ends three months following surgery

results in the ESIN group were classified as excellent for 16 patients (61.5%), good for 8 patients (30.8%), fair for 2 patients (7.7%), with no patients recording poor results at the last follow-up. In comparison, the results in the LCP group were excellent for 14 patients (50.0%), good for 5 patients (17.9%), fair for 6 patients (21.4%), and poor for 3 patients (10.7%). A significant difference was observed in the rates of excellent and good functional outcomes between the two groups ($P = 0.0412 < 0.05$).

Complications

Postoperative complications were observed in three patients in the ESIN group, which included one major complication (a case of ulnar nonunion) and two minor complications (one superficial wound infection and one dorsal sensory branch of ulnar nerve palsy). The nonunion occurred in a 45-year-old male with a Q3 distal ulnar fracture and was successfully treated through open reduction, autogenous bone grafting, and internal fixation, resulting in healing at approximately 28 weeks. The

Fig. 2 A 70-year-old female presented with a left ulna distal fracture in conjunction with a Q2 distal radius fracture resulting from a fall. (**A**) Preoperative anteroposterior and lateral radiographs indicated fractures of both the distal ulna and distal radius, with the distal ulna fracture classified as Q2 type. After performing open reduction and internal fixation of the distal radius fracture, an ulnar variance exceeding 3 mm was noted. (**B**) X-ray after surgery with cast. (**C**) Three months post-surgery, radiographs demonstrated callus formation at the fracture site. (**D**) X-ray results confirmed successful bone healing of the fracture six months after surgery

superficial wound infection was effectively managed with oral antibiotics and daily dressings. The dorsal sensory branch of ulnar nerve palsy resolved spontaneously without intervention.

In the LCP group, there were three major complications (one case of internal fixation breakage, one case of re-fracture and one case of extensor carpi ulnaris tendon rupture) as well as eight minor complications (three instances of superficial wound infections, two cases of dorsal sensory branch of ulnar nerve palsies, and three occurrences of hardware irritation). The internal fixation breakage occurred in a 32-year-old male with a Q6 distal ulnar fracture. Typical case is shown in Fig. 4. This case was successfully treated through open reduction, autogenous bone grafting, and hybrid fixation utilizing ESIN and LCP. The treatment resulted in healing at approximately 24 weeks. The case involves a 37-year-old woman who complained for hardware irritation six months post-surgery and requested the removal of her internal fixation. Approximately two weeks after the removal of immobilization, she accidentally fell on her wrist, resulting in a re-fracture. This re-fracture was treated successfully with closed reduction and cast immobilization for six weeks. The extensor carpi ulnaris tendon rupture occurred in a 43-year-old female patient four weeks postoperatively. The ruptured tendon was repaired using the palmar longus tendon from the ipsilateral limb, resulting in the restoration of the patient's extensor function six weeks after surgery. The three superficial wound infections were successfully treated with oral antibiotics and daily dressing changes. The two cases of dorsal sensory branch of ulnar nerve palsies resolved spontaneously. The three instances

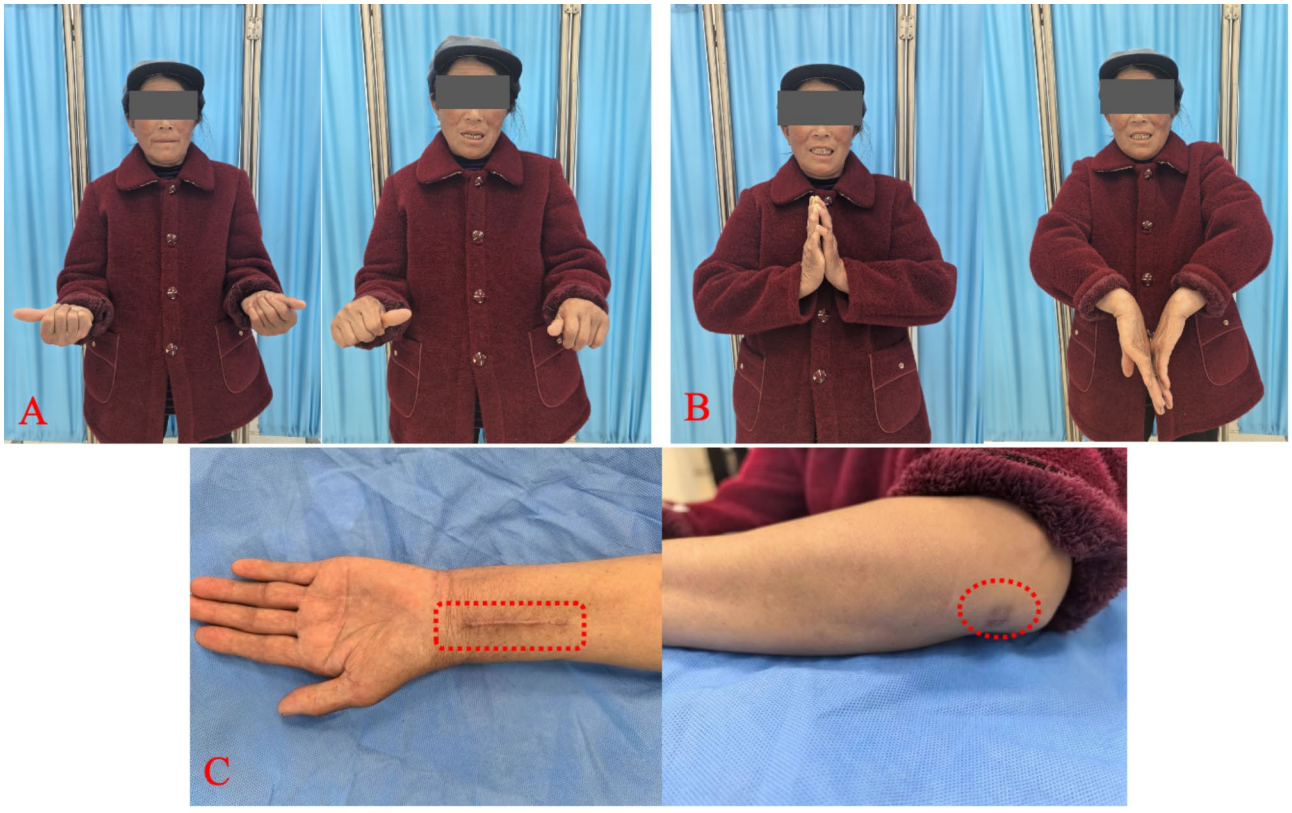

Fig. 3 Follow-up after three months post-surgery of the 70-year-old female patient who underwent ESIN fixation. (**A**) and (**B**) demonstrate satisfactory rotation (pronation and supination) as well as good flexion and extension of the wrist.(**C**) illustrates the two incisions on the radius and ulna

Fig. 4 A 34-year-old male presented with a Q6 distal fracture of the right ulna resulting from a strike injury. (**A**) Preoperative anteroposterior and lateral radiographs revealed a distal ulna fracture classified as Q6, which exhibited over one-third translation of the fracture surface. (**B**) One month postoperatively, radiographs indicated a lack of significant callus formation at the fracture site. (**C**) Three months following the operation, X-rays demonstrated that the internal fixation had failed due to stress concentration

of hardware irritation subsided following the removal of the internal fixation. Overall, the rates of major and minor complications were significantly different between the groups ($P < 0.05$; Table 3).

Discussion

Fractures of the distal ulna frequently occur in conjunction with fractures of the distal radius and other associated injuries [13]. While many fractures can be managed without surgical intervention, those that are misaligned or unstable may impair radioulnar functionality, necessitating surgical treatment [14, 32]. In their study, Biyani et al. [3] observed that two cases of comminuted distal ulna

fractures resulted in nonunion, whereas four out of five simple neck fractures exhibited significant limitations in rotational movement. Additionally, three cases demonstrated encroachment of callus into the distal radioulnar joint (DRUJ), which restricted forearm rotation in the 19 distal ulna fractures treated non-operatively. The authors further recommend that open reduction and internal fixation should be considered for distal ulna fractures that are unstable or irreducible, particularly those involving the styloid process, ulnar head, and distal ulnar metaphysis.

Anatomic fixation of distal ulna fractures presents significant technical challenges. Consequently, various surgical methods have been described, including percutaneous K-wires [3], Herbert screw placement [33], condylar blade plate [24], intrafocal pin plate [19], ulnar hook plate fixation [20], and locking plate fixation [23]. Each surgical technique presents its own advantages and disadvantages, and the choice of method is ultimately guided by the specific type of fracture and the surgeon's experience. In the context of centralized procurement for medical devices, there is currently a limited availability of internal fixation options, with locking plates remaining the predominant choice among most surgeons.

Currently, there are no satisfactory plate systems available for addressing unstable distal ulna fractures specifically targeting the ulnar head. Most existing products position the plate dorsally on the ulna, which can lead to irritation of the extensor tendons [34]. Furthermore, complications related to hardware prominence frequently necessitate additional surgical interventions for hardware removal [24]. Additionally, hardware failure following locking compression plate (LCP) fixation for distal ulna fractures is a common occurrence. Salvi described that the radius has a more complex function, including pronation and supination. The ulna plays a more significant role in maintaining the stability of the forearm than the radius, particularly during buckling and torsional stress [35]. The radius rotates around the ulna, which is crucial for maintaining stability during rotation. The distal metaphysis of the ulna serves as the area of stress concentration during rotation, making it susceptible to internal fixation breakage.

The titanium elastic nail is notable for its flexibility and moderate anti-rotation performance, allowing it to be adapted to the curvature of long bones [36]. The elastic stabilization intramedullary nail has demonstrated positive outcomes in the treatment of diaphyseal fractures in children and has also been utilized for forearm and clavicle fractures in adults [37–39]. The medullary cavity of the ulna is smaller than that of the radius, which facilitates the selection of an appropriately sized elastic stabilizing intramedullary nail. Retrograde intramedullary nails have demonstrated efficacy both in radius and ulna fractures in children [40, 41]. We propose that the distal ulna shares characteristics with the radial head, suggesting that distal ulna fractures could potentially be addressed using analogous techniques in adults. The elastic stabilization intramedullary nail could maintain the axial stability of the distal ulna, effectively disperse concentrated stress, and facilitate fracture healing through stable fixation rather than rigid fixation, in accordance with the BO principle. Intramedullary fixation not only stabilizes these fractures but also minimizes invasiveness, thereby reducing the risks of bone nonunion associated with soft tissue and periosteal dissection, as well as hardware prominence.

In a systematic review, Khalik reported that among 237 patients who opted for open reduction and internal fixation for distal ulnar fractures, the overall complication rate was 14.3 ± 21.3%. The two most common complications were nonunion and ulnar pain, occurring in 10% and 8% of cases, respectively. In contrast, the overall complication rate was 2.9 ± 7.0% in 209 patients who chose non-surgical treatment for distal ulnar fractures, with nonunion and chronic local pain syndrome being the leading complications at 4% and 1%, respectively. Additionally, in a cohort of 51 patients who underwent distal ulnar resection, the overall complication rate was 11.8 ± 9.7%, with ulnar pain and flexor tendon pathology accounting for 5% and 1% of cases, respectively. In our study, the incidence of complications associated with the treatment of distal ulnar fractures using locking compression plates (LCP) was comparable to those previously reported. However, the use of elastic stable intramedullary nailing (ESIN) for treating distal ulnar fractures significantly reduced the incidence of complications. These findings suggest that ESIN can effectively manage distal ulnar fractures while minimizing the overall complication rate [42].

To the best of our knowledge, there are currently no comprehensive studies available that focus on the application of ESIN in the treatment of distal ulnar fractures, which would allow for a direct comparison of outcomes. However, a prospective longitudinal study (EBM level II) conducted by Walz [41] demonstrated that 26 patients, with an average age of 73.6 years (ranging from 42 to 88 years), achieved bone healing in anatomical position in all cases within 6 to 12 weeks following closed reduction and anterograde elastic stable intramedullary nailing (ESIN), with subsequent treatment not involving immobilization. No length differences exceeding 2 mm and no clinically relevant deviations of the ulnar axis were observed. Aside from three cases of nail perforation at the distal end of the ulna, which did not result in any clinical manifestations, no complications were reported. In our study, one Q3 type ulnar distal comminuted fracture exhibited nonunion following the use of ESIN. However,

the complication rates were comparable between the two studies, indicating that the overall results were largely consistent. In our study, the ESIN group exhibited characteristics such as minimally invasive techniques, shorter surgery duration, fewer fluoroscopy times, a low complication rate, and a high rates of excellent and good outcomes for wrist joint function. Conversely, the LCP group experienced a greater number of major and minor complications, which adversely affected the overall functional outcomes.

In our study, the duration of immobilization was comparable between the ESIN and LCP groups. In the LCP group, we were concerned that excessive movement of the wrist could lead to hardware failure. Conversely, in the ESIN group, the technique did not offer sufficient rotational stability. Consequently, a cast or brace was utilized to maintain immobilization until primary callus formation occurred, which allowed for the initiation of wrist functional exercises. The difference in range of motion between the two groups was not statistically significant; however, the difference in functional outcomes was statistically significant. This discrepancy may be attributed to three factors unrelated to range of motion: residual deformity, subjective pain levels and complications. In the treatment of ulnar distal fractures, the use of ESIN demonstrated to reduce complications when compared to LCP. This advantage may be attributed to several factors: first, the procedure necessitates smaller surgical incisions, which results in less trauma and eliminates the requirement for anatomical exposure of critical nerves, blood vessels, and tendons. Second, intramedullary nails are placed within the medullary cavity, thereby minimizing irritation to the surrounding soft tissues of the ulna. Finally, patients treated with elastic stabilization intramedullary nails reported lower subjective pain scores in comparison to those in the LCP group.

It is important to acknowledge the inherent limitations of this research. Firstly, the limited sample size and the single-center nature of this study represent significant constraints that diminish the statistical robustness of the findings. Additionally, factors such as fracture patterns, soft tissue injuries, and the surgeons' familiarity with the implants introduce selection biases that could potentially influence outcomes. Furthermore, the short follow-up period constitutes another limitation of this study, restricting our ability to accurately assess the long-term efficacy of elastic stabilized intramedullary nails and locking compression plates in the treatment of distal ulnar fractures. Variations in surgeon performance and selection bias may also affect the generalizability of the study's findings. It is important to note that patients' expectations or concerns regarding treatment may influence their postoperative recovery and subjective experiences. Therefore, further investigation with a larger sample size and a multi-center study design is necessary to obtain more robust clinical data. We will also extend the follow-up duration to thoroughly observe the recovery process, complications, and long-term prognosis of patients. Employing third-party evaluators to collect and analyze data, or utilizing more objective imaging and biomechanical measures to assess efficacy, will further enhance the study's validity.

Conclusion

The ESIN fixation technique offers several advantages, including a reduction in the times of intraoperative fluoroscopy, shorter surgical times, lower complication rates, and favorable functional outcomes. Consequently, ESIN fixation is a viable and minimally invasive alternative to open reduction with internal fixation for treating unstable fractures of the distal ulna in adults.

Abbreviations

AP	Anteroposterior
DRUJ	Distal radioulnar joint
ESIN	Elastic stable intramedullary nails
LCP	Locking compression plate

Author contributions

C.C, D.H and A.C contributed equally to this work; C.C and Y.C coordinated the study; C.C, A.C and D.H wrote the paper; C.C, D.H, Y.X and Y.C are responsible for its execution, participant recruitment and operation technique; A.C and C.H collected relevant data and conducted statistical analysis. All the authors commented on the manuscript and approved the final version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethical approval

The study was approved by the Ethical Review Boards of the Beijing Jishuitan Hospital Guizhou Hospital.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Competing interests

The authors declare no competing interests.

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