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Original Article

Comparison of mini-plate versus Kirschner wire internal fixation for fifth metacarpal basal fractures with carpometacarpal joint dislocation

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Abstract: Objective: To compare the outcome of mini-plate versus Kirschner wire (K-wire) internal fixation for treating fifth metacarpal basal fractures with carpometacarpal joint dislocation. Method: A total of 46 patients with fifth metacarpal basal fractures combined with carpometacarpal joint dislocation were divided into two groups. The control group received K-wire fixation, while the observation group underwent mini-plate fixation. We assessed treatment effectiveness, surgical parameters, range of motion, serum stress markers, quality of life scores, and postoperative complication rates. A multivariable logistic regression analysis was performed to identify factors influencing postoperative joint function. Results: The observation group demonstrated a significantly higher excellent and good rate compared to the control group (P<0.05). Additionally, the observation group had a lower intraoperative bleeding volume, shorter incision lengths, and faster fracture healing times, all significant differences (all P<0.05). Postoperative assessments indicated that range of motion, quality of life scores, and superoxide dismutase levels were significantly improved in the observation group (P<0.05). Conversely, cortisol, angiotensin II, and norepinephrine levels, along with the incidence of postoperative complications, were lower in the observation group compared to the control group (all P<0.05). Logistic regression analysis identified the surgical method as an independent factor affecting postoperative metacarpal joint function (OR = 0.16, P = 0.003). Conclusion: Mini-plate internal fixation is superior to K-wire fixation for the treatment of fifth metacarpal basal fractures with carpometacarpal joint dislocation. It promotes faster fracture healing, reduces serum stress markers, enhances joint mobility and quality of life, and decreases postoperative complications.

Keywords: Fifth metacarpal basal fracture, carpometacarpal joint dislocation, mini-plate internal fixation, Kirschner wire internal fixation

Introduction

Basal fractures of the fifth metacarpal bone, often triggered by forceful actions, are frequently accompanied by dislocation of the carpometacarpal joint [1, 2]. The hand, a critical organ for fine motor functions, plays an integral role in daily life. Inappropriately managed or delayed treatment can lead to various complications including pain, dysfunction in wrist joint movement, weakness, joint stiffness, and degeneration [3]. Such outcomes significantly impair patient quality of life.

Various therapeutic options are available for managing this injury, ranging from conservative plaster fixation to surgical interventionssuch as Kirschner wire (K-wire) fixation and mini-plate internal fixation [4, 5]. Historically, manual reduction followed by plaster external fixation was commonly used, but these methods required prolonged immobilization, leading to potential complications such as joint deformities and stiffness, which worsened the recovery of hand function [6].

Advancements in surgical techniques, materials, and nursing care, coupled with patient demands for quicker rehabilitation, have led to a preference for K-wire and mini-plate fixations in modern surgical practice. Mini-plate fixation offers reliable stability and enables early postoperative activity but is less suitable for comminuted fractures [7]. Some studies reported

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mini-plate fixation had drawbacks such as significant tissue damage and high cost [8]. On the other hand, K-wire fixation, an intramedullary fixation method, is minimally invasive, cost-effective, and readily available. However, its application can be unsatisfactory due to a high rate of surgical sequelae and less reliable fixation results [9, 10].

Extensive research has compared the therapeutic effects of mini-plate and K-wire fixation from various perspectives [11, 12]. Yet, there remains no consensus among scholars regarding the optimal fixation method for treating fifth metacarpal basal fractures with carpometacarpal joint dislocation [13, 14]. This study involved 46 patients with such injuries, caused by hand trauma, who were divided into two treatment groups: mini-plate or K-wire fixation. Their clinical outcomes were compared to provide clinical evidence for the efficacy of these treatment options.

Materials and methods

General information

This retrospective study was conducted at the Department of Hand and Foot Surgery, Hangzhou Fuyang Hospital of TCM Orthopedics and Traumatology, from June 2018 to June 2023. It included 46 patients diagnosed with a basal fracture of the fifth metacarpal bone accompanied by carpometacarpal dislocation. Patients were informed about the advantages and limitations of the two different treatment methods - mini-plate internal fixation and K-wire internal fixation - and subsequently chose their preferred treatment. The participants were evenly divided into two groups: the observation group (n = 23), treated with mini-plate internal fixation, and the control group (n = 23), treated with K-wire internal fixation. This study received approval from the Ethics Committee of Hangzhou Fuyang Hospital of TCM Orthopedics and Traumatology (Approval No. 2018-034).

Inclusion criteria: (1) Age between 18 and 60 years old. (2) No comminuted fractures. (3) Confirmation of fifth metacarpal bone with carpometacarpal dislocation through X-ray and computed tomography scans. (4) Presence of a fresh fracture. (5) Normal cognitive function, allowing for effective communication. (6) Availability of complete and standardized medical records, including historical medical data, preoperative laboratory and imaging results, intraoperative data, and serum stress markers.

Exclusion criteria: (1) Presence of pathologic fractures. (2) Concurrent fractures in other parts of the hand. (3) Multiple fractures or autoimmune diseases affecting the metacarpophalangeal joints. (4) Existence of malignant tumors or significant organ dysfunction. (5) Coagulation disorders or other conditions precluding surgical intervention. (6) Damage to blood vessels or nerves associated with the fracture.

Methods of treatment

In the control group, patients underwent K-wire internal fixation surgery. The procedure was as follows: (1) The patient was placed in a supine position, and brachial plexus block anesthesia was administered. A 3 cm incision was made on the radial dorsal side, centered on the fracture line. (2) Tissue layers were separated to fully expose the fracture site, clearing any blood clots and soft tissue. (3) Fracture reduction was aided by a C-arm fluoroscope. Upon achieving clinically satisfactory results - ensuring integrity and a smooth articular surface - a 1 mm diameter K-wire was inserted in both anterograde and retrograde directions, securing the fracture ends while safeguarding adjacent tissues. (4) After verifying the correct positioning of the K-wire, its tail was bent, cut, and left protruding from the skin. The limb was then immobilized with a plaster support, which was removed after 3 weeks. (5) Once the anatomical position of the fracture was confirmed as satisfactory, a drainage tube was placed, and the incision was sutured.

In the observation group, patients received mini-plate internal fixation surgery, utilizing the same anesthesia and reduction techniques as the control group. The steps included: (1) A T-shaped locking steel plate was positioned on the radial side and secured with two screws. (2) With C-arm fluoroscopic assistance, the placement was confirmed, and 1-2 spiral nails (2 mm) were used to stabilize the fracture ends, depending on the specific situation. (3) After confirming satisfactory reduction, the incision fascia was sutured to cover the entire fixation plate, preventing tendon adhesion. (4) The incision was closed following the placement of a drainage tube.

Data collection

Preoperative data: Information was gathered from patient records, including gender, age, BMI, fracture type, injury cause, and time from injury to surgery.

Intraoperative data: Surgical time, intraoperative bleeding volume, incision length, and fracture healing time were documented from medical records.

Postoperative data: These included range of motion (ROM), levels of serum stress- markers, incidence of postoperative complications, and quality of life scores. For cases with postoperative complications, diagnoses were verified by two experienced specialists.

Outcome measures

In this study, the primary index was the treatment effect, and the secondary indexes included surgical conditions, ROM, levels of serum stress markers, quality of life scores, and incidence of postoperative complications.

(1) Treatment effects: Comparison of treatment outcomes between the two groups was based on the following evaluative criteria [15]: an excellent result was defined as a metacarpal ROM between 70° and 90°; a good result as a ROM between 30° and 69°; and a poor result as a ROM ≤29°. The excellent and good rate was calculated using the formula: (number of cases with excellent and good/total number of cases) × 100.

(2) Surgical conditions: These included surgical time, intraoperative bleeding volume, incision length, and fracture healing time. The incidences of these conditions were compared between the two groups.

(3) ROM: The ROM of the metacarpophalangeal joint was assessed using the total active motion scoring system by the American Society for Surgery of the Hand before and one week after surgery [16].

(4) Serum stress markers: Levels were measured before and one week post-surgery. 3 ml of fasting venous blood was collected, centrifuged, and the serum separated for analysis. Levels of superoxide dismutase (SOD), cortisol (Cor), angiotensin-II (Ang-II), and norepinephrine (NE) were quantified using ELISA kits from Hangzhou Hongya Technology Co., Ltd., following the manufacturer's instructions [17].

(5) Quality of life scores: These were evaluated using the European Five Dimensional Scale (EQ-5D) before and one week post-surgery. The scale consists of five dimensions, with a maximum score of 10 points per dimension, reflecting the patient's quality of life [18].

(6) Postoperative complications: The incidence of complications such as tendon adhesion, malformed cicatrisation, and anchylosis was assessed three months post-surgery. The incidence rate was calculated using the formula: The incidence rate of postoperative complications = [(number of cases with postoperative complications)/total number of cases] × 100%.

Statistical analysis

Data were analyzed using SPSS version 21.0. Measured data were presented as mean ± standard deviation (SD) and analyzed using independent and paired t-tests. Categorical data were presented as percentages/cases and analyzed with the χ^2 test. Multivariable regression analysis was performed using logistic regression to identify factors affecting metacarpal joint function after surgery. A *p*-value <0.05 was considered significant.

Results

Comparison of general information

As described in **Figure 1** and **Table 1**, this study included 23 patients who received mini-plate internal fixation surgery and another 23 who underwent K-wire internal fixation surgery. There were no significant differences in gender, age, body mass index, presence of hypertension or diabetes, smoking status, fracture type, injury causes, or time from injury to surgery between the observation and control groups (all P>0.05), making them comparable.

Comparison of treatment effects

Table 2 shows the treatment outcomes: in the observation group, 16 patients achieved excellent results, 6 had good results, and 1 had poor

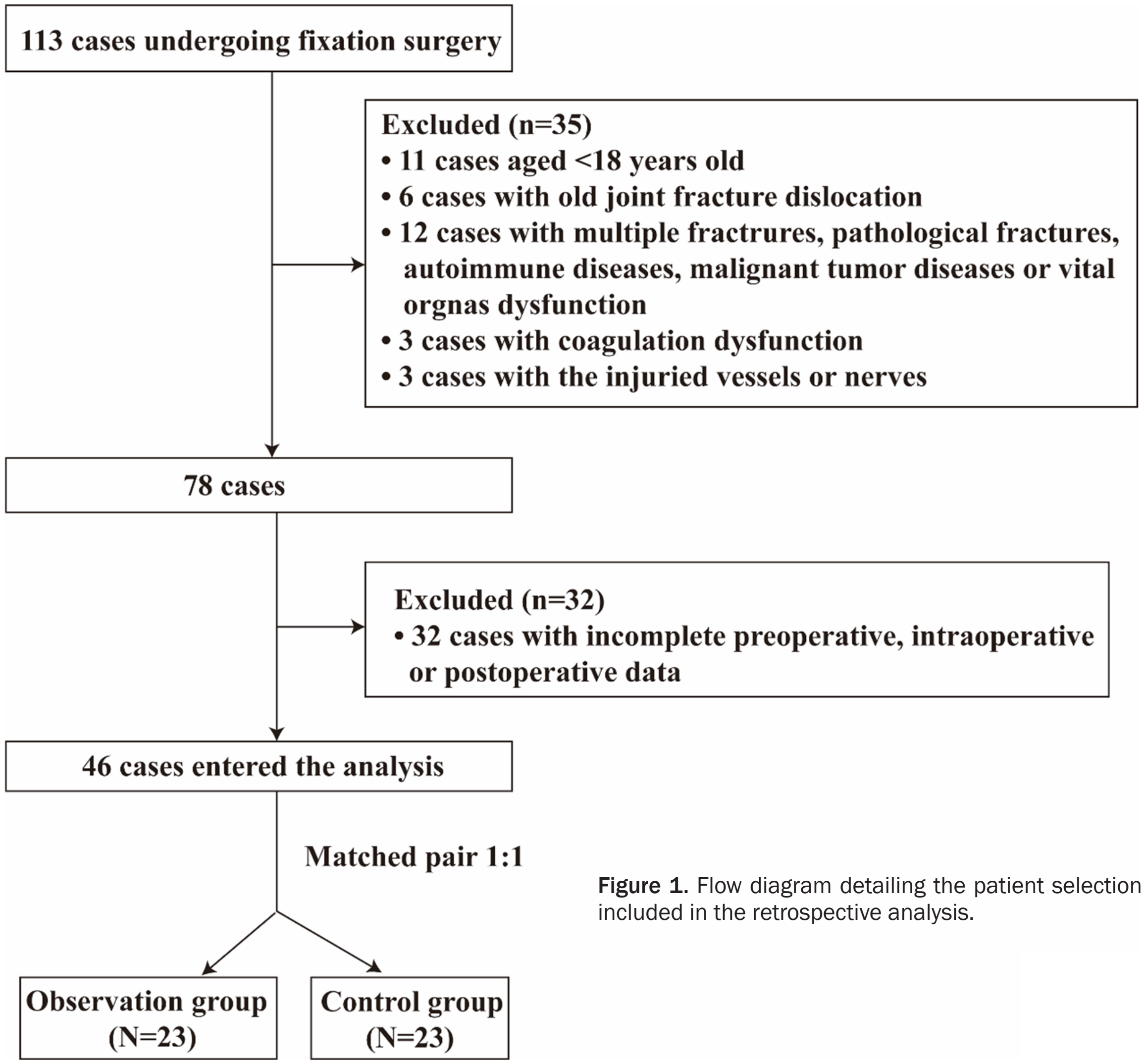

Figure 1. Flow diagram detailing the patient selection included in the retrospective analysis.

results. In contrast, in the control group, 10 patients had excellent results, 7 had good results, and 6 had poor results. The total efficacy rate in the observation group was 95.65%, significantly higher than 73.91% in the control group (P = 0.040).

Comparison of surgical conditions

The average surgical time was 22.09±4.12 minutes for the observation group and 24.01±3.98 minutes for the control group, with no significant differences observed. However, intraoperative bleeding volume (25.28±3.91 mL), incision length (3.18±0.53 cm), and fracture healing time (8.14±1.83 weeks) were significantly lower in the observation group compared to the control group (all P<0.05), as detailed in **Table 3**.

Comparison of joint mobility

As indicated in **Table 4**, there were no significant differences in ROM between the two groups prior to treatment (P>0.001). Post-treatment, ROM significantly increased in both groups compared to pre-treatment values (both P<0.05). Post-treatment, the observation group showed significantly greater improvements in extension (93.28±5.18° vs. 82.36±4.38°, P<0.001) and flexion (97.27±4.22° vs. 90.17±3.81°, P<0.001) compared to the control group.

Comparison of serum stress markers

As indicated in **Table 5**, no significant pre-treatment differences were observed in the levels of SOD, Cor, Ang-II or NE levels between the

Table 1. Comparison of general information

Data	Observation group (n = 23)	Control group (n = 23)	t/χ^2 value	*P* value
Gender			0.365	0.546
Male	15	13		
Female	8	10		
Age (years)	37.21±3.09	36.98±2.98	0.257	0.798
BMI (kg/m^2)	22.87±3.18	22.91±3.09	0.043	0.967
Diabetes (cases)	2	3	0.224	0.636
Hypertension (cases)	3	4	0.169	0.681
Smoking (cases)	5	4	0.138	0.710
Fracture type (Cases)			1.460	0.227
Closure	12	16		
Open	11	7		
Causes of injury (Cases)			0.612	0.709
Fall damage	6	7		
Machine injury	9	5		
Fist injury	8	11		
Time from injury to surgery (d)	3.27±0.61	3.19±0.54	0.446	0.658

Note: BMI: Body mass index.

Table 2. Comparison of treatment effects (cases)

Group	Excellent	Good	Poor	Excellent and good rate (%)
Observation group (n = 23)	16	6	1	95.65
Control group (n = 23)	10	7	6	73.91
χ^2 value	3.185	0.451	4.213	4.213
P value	0.074	0.502	0.040	0.040

Table 3. Comparison of surgical conditions ($\overline{X}$±SD)

Group	Surgical time (min)	Preoperative bleeding (mL)	Length of incision (cm)	Fracture Healing Time (Weeks)
Observation group (n = 23)	22.09±4.12	25.28±3.91	3.18±0.53	8.14±1.83
Control group (n = 23)	24.01±3.98	29.17±3.65	4.28±0.47	9.32±1.93
t value	1.607	3.488	7.447	2.128
P value	0.115	0.001	<0.001	0.039

Table 4. Comparison of the range of motion ($\overline{X}$±SD, °)

Group	Straightening		Flexion	
	Before surgery	After surgery	Before surgery	After surgery
Observation group (n = 23)	61.83±4.21	93.28±5.18	64.29±3.92	97.27±4.22
Control group (n = 23)	60.98±5.01	82.36±4.38	63.87±3.86	90.17±3.81
t value	0.623	7.720	0.366	5.989
P value	0.537	<0.001	0.716	<0.001

observation and control groups (all P>0.05). Post-treatment, levels of all indicators, except for SOD, significantly decreased in both groups compared to their baseline values (all P<0.05). Notably, after treatment SOD levels in the observation group (108.23±10.37) were higher

Table 5. Comparison of serum stress markers before and after surgery ($\overline{X}$±SD)

Groups	SOD (nU/mL)		Cor (nmol/L)		Ang-II (ng/mL)		NE (ng/L)	
	Before surgery	After surgery	Before surgery	After surgery	Before surgery	After surgery	Before surgery	After surgery
Observation group (n = 23)	87.14±6.11	127.31±9.31**	209.34±11.36	132.04±7.34**	21.98±4.23	12.09±2.18**	382.18±23.47	201.24±20.45**
Control group (n = 23)	87.93±5.93	108.23±10.37**	208.97±10.64	151.28±8.34**	21.73±5.13	15.28±3.23**	381.97±22.57	251.29±21.04**
t value	0.445	6.566	0.114	8.305	0.180	3.925	0.031	8.181
P value	0.659	<0.001	0.909	<0.001	0.858	<0.001	0.976	<0.001

Note: SOD: Superoxide dismutase; Cor: Cortisol; Ang II: Angiotensin-II; NE: Norepinephrine; **P<0.001 vs before surgery in the same group.

Table 6. Comparison of life quality scores before and after surgery ($\overline{X}$±SD, Scores)

Group	Activity ability		Self-care ability		Living ability		Pain and Discomfort		Anxiety and depression	
	Before surgery	After surgery	Before surgery	After surgery	Before surgery	After surgery	Before surgery	After surgery	Before surgery	After surgery
Observation group (n = 23)	3.87±0.41	7.31±0.56	4.28±0.37	7.92±1.27	4.01±0.62	7.28±1.32	3.71±0.52	7.39±1.32	4.21±0.62	7.32±1.36
Control group (n = 23)	3.81±0.52	6.21±0.42	4.31±0.31	5.28±0.84	3.98±0.51	6.29±0.84	3.68±0.40	5.98±0.89	4.18±0.52	6.39±0.78
t value	0.434	7.536	0.298	8.315	0.179	3.034	0.219	4.248	0.178	2.845
P value	0.666	<0.001	0.767	<0.001	0.859	0.004	0.827	<0.001	0.859	<0.001

Table 7. Comparison of postoperative complications

Group	Adhesion of tendon	Malformed cicatrisation	Anchylosis	Total incidence rate (%)
Observation group (n = 23)	1	0	1	8.70
Control group (n = 23)	2	3	3	34.78
χ^2 value	0.357	3.209	1.095	4.600
P value	0.550	0.073	0.295	0.032

Table 8. Assignments of independent and dependent variables for logistic regression

Data	Variable	Assignments description
Evaluation of metacarpal joint function	Y	Excellent and good = 0; Poor = 1
Age (years)	X1	≤35 = 0; >35 = 1
Fracture type	X2	Closure = 0; Open = 1
Time from injury to surgery (d)	X3	≤3 = 0; >3 = 1
The method of surgery	X4	Mini plate internal fixation = 0 Kirschner wire internal fixation = 1

Table 9. Results of logistic regression analysis for factors affecting metacarpal joint function after surgery

Data	Regression coefficient	Standard error	Wald value	Degree of freedom	*P* value	OR	95% CI
Age	2.45	1.18	4.19	1	0.065	9.98	0.95-36.87
Fracture type	1.26	0.74	2.80	1	0.095	3.61	0.80-16.13
Time from injury to surgery	1.36	1.61	0.74	1	0.391	4.12	0.17-45.89
The method of surgery	-1.79	0.64	8.49	1	0.003	0.16	0.04-0.59

Note: OR: Odds ratio; CI: Confidence interval.

than in the control group (127.31±9.31, P<0.001), while levels of Cor (132.04±7.34 vs. 151.28±8.34, P<0.001), Ang-II (12.09±2.18 vs. 15.28±3.23, P<0.001), and NE (201.24±20.45 vs. 251.29±21.04, P<0.001) were significantly lower.

Comparison of life quality scores

As detailed in **Table 6**, no significant differences were found between the groups before treatment regarding scores of activity ability, self-care, living ability, pain and discomfort, or anxiety and depression(all P<0.05). After treatment, significant improvements were noted in all dimensions for both groups (all P<0.05). The post-treatment scores in the observation group were significantly higher than those in the control group in all evaluated dimensions (all P<0.001).

Comparison of incidences of postoperative complications

As shown in **Table 7**, the observation group reported one case each of tendon adhesion and anchylosis. In contrast, the control group had two cases of tendon adhesion, three cases of malformed cicatrisation, and three cases of anchylosis. The total incidence rate of postoperative complications was significantly lower in the observation group compared to the control group (8.70% vs. 34.78%, P = 0.032).

Logistic regression results

The assignment of variables for logistic regression analysis is shown in **Table 8**. The logistic regression results, as detailed in **Table 9**, indicated that the method of surgery was an independent factor affecting post-surgery metacarpal joint function, with an OR of 0.16 (P = 0.003). This finding underscores the significant impact of surgical choice on functional outcome.

Discussion

Basal fractures of the fifth metacarpal bones with carpometacarpal joint dislocation, resulting from hand trauma, are clinically prevalent. Previous studies indicate that these fractures constitute approximately 32% of all metacarpal fractures [13]. Prompt and appropriate treatment is crucial to prevent dysfunction and malformation. Effective treatment requires not only satisfactory anatomical reduction but also firm fixation while minimizing damage to nearby tendons, nerves, blood vessels, and other tissues [19, 20]. It is equally important to preserve blood supply to facilitate early recovery.

Traditionally, K-wire fixation has been a common surgical method for these fractures, known for achieving good reduction outcomes [21]. However, issues with unstable fixation have led to suboptimal recovery of joint function in some patients. Open reduction has been increasingly recognized for its ability to directly assess and manage the fracture, maintaining articular surface integrity and promoting post-operative recovery [22]. Each surgical technique has specific indications and varying effectiveness [23]. While K-wire fixation is simple and minimally invasive, it may inadvertently damage surrounding tissues and fail to control rotation and length adequately, impacting the quality of anatomic reduction [24]. Moreover, the necessity to operate through the articular surface can hinder early functional exercises and pose risks of joint damage. Particularly for fractures with associated dislocation, the distal support provided by K-wire is often insufficient, predisposing to re-displacement [25].

Mini-plate internal fixation, on the other hand, offers robust resistance to bending and rotation, effectively countering the forces exerted by hand muscles. This method facilitates dressing changes and the recovery of open wounds without the need for external fixation [26]. As long as sufficient bone fragments are available for screw placement, mini-plate fixation can be applied broadly and is effective for both distal and proximal fractures of the metacarpal and phalangeal bones, including intra-articular fractures [26]. The efficacy of mini-plate fixation is evidenced by the high rate of excellent or good outcomes (95.65%) compared to the control group (73.91%). Studies consistently demonstrate that mini-plate fixation shortens healing time and improves ROM, thereby enhancing the overall recovery process for fractures of the fifth metacarpal bones with carpometacarpal joint dislocation [27, 28]. This method not only accelerates fracture healing but also ensures better recovery of joint mobility, confirming its advantageous effects in clinical settings.

The stress response is a protective mechanism of body tissues that reacts to changes in both internal and external environments. Strong stressors can induce pathologic changes in body tissues and precipitate disease onset [29]. Fractures and surgical treatments can damage body tissues, elicit potent oxidative stress responses, and subsequently intensify the activity of sympathetic nerves and adrenal glands, leading to the production of numerous oxidative stress factors [30]. SOD is an antioxidant enzyme that plays a critical role in protecting specific tissues from oxidative stress damage by scavenging oxygen free radicals, thereby preserving cellular function. Cortisol (Cor) facilitates protein breakdown and enhances tissue tolerance, aiding in tissue repair post-injury. NE acts as a vasoactive agent from the adrenal medulla, promoting vascular contraction and maintaining vascular perfusion under trauma or stress, thus supporting internal and external balance [31]. Ang-II enhances blood flow and vascular contraction, and stimulates substantial aldosterone secretion [32].

This study demonstrated that SOD levels were higher in the observation group, whereas Cor, NE, and Ang-II levels were lower compared to the control group. This suggests that mini-plate fixation imposes a lesser stimulus on body tissues, thereby reducing serum stress-related indicators and facilitating post-surgical recovery.

Furthermore, quality of life scores were higher in the observation group, implying that mini-plate internal fixation can effectively enhance patient quality of life. The potential reasons include firm fixation by the mini-plate, which does not impede finger function during recovery. The plate's small size and lateral placement are advantageous for bone grafting or tendon repair, further improving quality of life. From a safety perspective, the incidence rate of postoperative complications was significantly lower in the observation group (8.70%) compared to the control group (34.78%), highlighting the high safety of mini-plate fixation. However, during mini-plate fixation treatment, it is crucial to ensure sufficient soft tissue coverage to prevent later-stage fracture, confirm proper fracture reduction before screw placement, and avoid stress concentration that could lead to plate fracture.

Nevertheless, this study's limitations include its single-center design, lack of subgroup comparisons, absence of long-term follow-up results, and no exploration of related mechanisms. Future research should involve high-quality, multicenter, controlled studies with long-term follow-up and a larger participant pool to validate these findings.

In conclusion, mini-plate internal fixation for the treatment of fifth metacarpal base fractures with carpometacarpal joint dislocation effectively promotes fracture healing, reduces serum stress markers, improves joint mobility and quality of life, and diminishes postoperative complications.

Disclosure of conflict of interest

None.

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