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Original Article

Dual mini-plate vs. T-plate fixation for Edinburgh type IB proximal clavicle fractures: a comparative clinical study

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Abstract: Objective: To compare the clinical efficacy of dual mini-plate fixation and T-plate fixation in the management of Edinburgh type IB proximal clavicular fractures (PCFs). Methods: A total of 100 patients with PCF who underwent surgical treatment using either dual mini-plate fixation (mini-plate group) or a T-plate fixation (T-plate group). Therapeutic efficacy, operative parameters, recovery metrics, postoperative complications, subjective pain, upper extremity function, shoulder range of motion, and serum bone metabolic markers were compared between the two groups. Results: Clinical outcomes favored the mini-plate approach over the T-plate technique. Operation time and intraoperative blood loss did not differ statistically between groups. However, the mini-plate procedure resulted in a smaller incision, shorter hospital stay, faster fracture healing, earlier return to work, fewer complications, and greater improvements in pain relief, upper limb function, shoulder mobility, and bone metabolic activity. Conclusion: For Edinburgh type IB PCFs, dual mini-plate fixation provides superior clinical efficacy over T-plate fixation, promoting faster recovery and improved functional outcomes.

Keywords: Proximal clavicle fractures, Edinburgh type IB, dual mini-plate fixation, T-plate fixation

Introduction

Clavicle fractures are among the most common skeletal injuries, for 5%-10% of all fracture cases, with males exhibiting a nearly threefold higher incidence than females [1, 2]. Proximal clavicle fractures (PCFs), involving the medial third of the clavicle, are particularly rare, representing only about 2% of all clavicle fractures [3]. Their occurrence is attributed to the unstable connection between clavicle and shoulder girdle, often resulting in a "floating clavicle" phenomenon [4].

While conservative managements, including sling immobilization and oral non-steroidal anti-inflammatory drugs (NSAIDs), aid in fracture union and symptom relief (e.g., pain, swelling), they carry the risk of nonunion and chronic shoulder dysfunction. Consequently, most domestic and international scholars now advocate for open reduction and internal fixation for PCFs. Nevertheless, the optimal fixation strategy for severely displaced cases remains unclear and controversial [5, 6]. Previous studies have emphasized that fracture-specific fixation techniques yield superior outcomes [7]. The dual mini-plate technique provides sufficient multi-planar stability through thinner orthogonal plates, effectively resisting torsional and axial stresses [8, 9]. In displaced midshaft clavicle fractures, this method reduces the need for implant removal without compromising bone union rates [10]. However, its clinical application is constrained by several factors: the procedure is technically demanding, the implant can cause hardware prominence or skin irritation, and excessive periosteal coverage can affect local hemodynamics at the fracture ends [11].

In contrast, T-plates, characterized by high screw-hole density, a smaller distal surface contact area, and strong local screw-holding strength at the T-end, enable firm fixation of fracture fragments [12]. Li et al. [13] demonstrated

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that T-plate use with locking compression plates for complex tibial plateau fractures reduces tissue damage and facilitates early postoperative mobilization. However, due to the complex curvature and variable morphology of the proximal clavicle, the T-plate often fails to achieve anatomical conformity. It also offers limited flexibility in screws orientation for comminuted fractures and may lead to stress concentration, predisposing to plate break or refracture after hardware removal [14].

Given the scarcity of comparative studies between T-plate versus dual mini-plate fixations for Edinburgh type IB PCFs, the present study aims to perform a detailed evaluation to inform clinical decision-making.

Materials and methods

Case selection

Inclusion criteria: ① Adults (>18 years) with fresh, closed clavicle fractures; ② Edinburgh type IB fractures (medial 3.0 cm of clavicle) [15]; ③ Fracture displacement >1.0 cm; ④ Normal pre-injury shoulder function; ⑤ Non-pathological fractures; ⑥ Complete clinical and follow-up records. Exclusion criteria: ① Minors (<18 years) with fresh closed fractures; ② Pathological or open fractures; ③ Concurrent ipsilateral scapular fractures; ④ Pre-existing peri-shoulder neurovascular pathologies; ⑤ Prior shoulder surgery; ⑥ Incomplete follow-up or missing clinical data.

Case data

A total of 100 patients with PCF (Edinburgh type IB) who met the above criteria and completed full follow-up were retrospectively enrolled between January 2006 and January 2024. According to fixation methods, participants were categorized into a mini-plate group (n=57; dual mini-plate fixation) and a T-plate group (n=43; T-plate internal fixation). This study was reviewed and approved by the Ethical Committee of Dongying People's Hospital.

Surgical methods

Surgery was performed under brachial plexus block or general anesthesia (GA). Patients were positioned in the beach-chair position. A supraclavicular incision was made, followed by layer-by-layer dissection from the superficial to deep layers until the periosteum was exposed at the fracture site. The exposure was extended medially to the clavicular sternal end, with concurrent exposure of the sternoclavicular joint. Following subperiosteal elevation and exposure of fracture ends, interposed soft tissues were debrided, and anatomical reduction was achieved under direct vision. When indicated, temporary fixation was performed using absorbable suture cerclage or Kirschner-wires.

Mini-plate group: After reduction, dual mini-plates were applied along the superior and anterior surfaces of the clavicle, corresponding to the extent of the proximal fracture, to stabilize both proximal and distal segments with cortical screws. During this process, care was taken to prevent screw penetration into the sternoclavicular joint space. T-plate cohort: Subsequent to anatomical reduction, a customized T-plate was used for fixation, with 2-3 screws securing the proximal segment and 3-4 screws securing the distal segment. Intraoperative fluoroscopy was performed to confirm proper reduction and rule out screw encroachment into the sternoclavicular joint.

Postoperative treatment

A single dose of prophylactic antibiotics was administered postoperatively to prevent infection. Shoulder rehabilitation, which involved both patient-initiated movements and therapist-assisted exercises, was initiated 48 hours after surgery under physiatrist supervision. Follow-up X-ray examinations were conducted at scheduled intervals to evaluate fracture healing progress.

Outcome measures and efficacy evaluation

Efficacy assessment: Therapeutic efficacy was categorized as markedly effective, partially effective, or ineffective. Markedly effective: Complete fracture union confirmed radiographically by continuous callus formation without displacement; Visual Analogue Scale (VAS) score ≤2; Disabilities of the Arm, Shoulder and Hand (DASH) score ≤10; and shoulder range of motion (ROM) ≥90% of the contralateral side. Partially effective: Radiographs showing clear evidence of healing (linear callus present, no clinical instability), with VAS score 3-4, DASH score 11-30, and shoulder ROM 70-89% of the unaffected side. Ineffective: Presence of nonunion or internal fixation loosening, VAS score ≥5, DASH score >30, shoulder ROM <70% of the contralateral side, or the need for revision surgery. Effective rate = (markedly effective cases + partially effective cases)/total cases * 100%.

Operative parameters: Operation duration, incision length, and intraoperative blood loss were recorded for both groups.

Postoperative rehabilitation parameters: Duration of hospitalization, fracture healing time, and time to return to work were collected and compared.

Postoperative complications: The incidences of internal fixation loosening, surgical site infection, infraclavicular brachial plexus irritation, and shoulder stiffness were recorded, and the overall morbidity rate was calculated. Internal fixation loosening was defined as plate tilt ≥1 mm or fracture segment displacement ≥2 mm on radiographs [16].

Pain evaluation: Pain intensity was measured using the VAS preoperatively and at 2 weeks, 1 month, and 3 months postoperatively [17].

Functional recovery: Upper limb function was assessed using the DASH questionnaire [18] before surgery and 3 months postoperatively. The scale covers symptom (0-40), functional (0-50), and social/psychological (0-10) domains. A lower total score indicates better recovery.

Shoulder joint mobility: Active shoulder forward flexion and abduction were measured preoperatively and 3 months postoperatively in both groups using a circular goniometer.

Serum bone metabolism markers: Preoperatively and 3-months postoperatively, fasting venous blood samples (3 mL) were collected in the morning and analyzed by enzyme-linked immunosorbent assay (ELISA) to quantify osteocalcin (BGP), procollagen type I C-terminal propeptide (PICP), and cross-linked C-telopeptide of type I collagen (CTX-1) levels.

Statistical methods

All data were analyzed using SPSS 20.0. Categorical variables, such as gender distribution, fracture laterality, and complication rates, were expressed as frequencies (n) and compared using the chi-square (χ^2) test. Continuous variables (e.g., age, operative time, incision length, intraoperative blood loss, DASH scores) were assessed for homogeneity of variance using Bartlett's test and for normality using the Kolmogorov-Smirnov test. Normally distributed data with equal variances were presented as mean ± standard deviation (SD) and compared between groups using the independent-samples t-test. A P value of <0.05 was considered statistically significant.

Results

Comparison of baseline characteristics between the two groups

No significant differences were observed between the mini-plate and T-plate groups in terms of sex, age, involved side, Edinburgh classification, or mechanism of injury (P>0.05; **Table 1**).

Comparison of treatment efficacy between the two groups

The overall treatment efficacy was 91.23% (52 effective cases) in the mini-plate group, significantly higher than 74.42% (32 effective cases) in the T-plate group (P=0.023; **Table 2**).

Comparison of operative variables between the two groups

No significant intergroup differences were found in operative duration or intraoperative blood loss (P>0.05); however, the mini-plate group had a significantly smaller incision length than the T-plate group (P<0.001; **Table 3**).

Comparison of rehabilitation parameters between the two groups

Compared with the T-plate group, the mini-plate group exhibited significantly shorter hospitalization, faster fracture healing, and earlier return to work (P<0.05; **Table 4**).

Comparison of postoperative complications between the two groups

Postoperative complications included internal fixation loosening, surgical site infection, infraclavicular brachial plexus irritation, and shoulder stiffness. The corresponding frequencies

Table 1. Comparison of baseline characteristics between the two groups

Variable	Mini-plate group (n=57)	T-plate group (n=43)	χ^2/t	P
Sex			0.537	0.464
Male	40 (70.18)	33 (76.74)		
Female	17 (29.82)	10 (23.26)		
Age (years)	45.37±12.69	41.05±11.62	1.747	0.084
Involved side			1.026	0.311
Left	11 (19.30)	12 (27.91)		
Right	46 (80.70)	31 (72.09)		
Edinburgh classification			0.187	0.666
IB1	15 (26.32)	13 (30.23)		
IB2	42 (73.68)	30 (69.77)		
Cause of injury			0.268	0.875
Traffic accident	40 (70.18)	32 (74.42)		
Fall	15 (26.32)	10 (23.26)		
Other injuries	2 (3.51)	1 (2.33)		

Table 2. Comparison of treatment efficacy between the two groups

Variable	Mini-plate group (n=57)	T-plate group (n=43)	χ^2	P
Markedly effective	28 (49.12)	13 (30.23)		
Partial effective	24 (42.11)	19 (44.19)		
Ineffective	5 (8.77)	11 (25.58)		
Overall effectiveness	52 (91.23)	32 (74.42)	5.153	0.023

were 2, 1, 2, and 2 in the mini-plate group and 6, 3, 3, and 4 in the T-plate group, respectively. The overall incidence of complications was significantly lower in the mini-plate group (P=0.003; **Table 5**).

Comparison of VAS score between the two groups

Preoperative VAS scores did not differ significantly between the two groups (P>0.05). However, both groups showed progressive pain reductions at 2 weeks, 1 month, and 3 months after surgery, with the mini-plate group showing significantly lower scores than the T-plate group at all postoperative time points (P<0.05; **Table 6**).

Comparison of DASH scores between the two groups

Preoperative DASH scores, including the symptom, functional, and social/psychological domains, as well as the total score, were comparable between groups (P>0.05). Postoperatively, all DASH scores reduced markedly in both groups, with the mini-plate group achieving lower scores than the T-plate group (P<0.05; **Figure 1**).

Comparison of joint mobility between the two groups

A comparative analysis of shoulder mobility was performed, assessing flexion and abduction pre- and post-operation. Preoperative ROM showed no statistical inter-group difference (P>0.05); Postoperatively, both groups demonstrated significant improvements in ROM; however, the mini-plate group achieved greater flexion and abduction than the T-plate group (P<0.05; **Figure 2**).

Comparison of serum bone metabolism markers between the two groups

Serum bone metabolism markers were compared between the two groups. Preoperative marker levels showed no significant differences (P>0.05). At 3 months postoperatively, BGP and PICP levels increased significantly, whereas CTX-1 decreased in both groups. Moreover, the mini-plate group exhibited significantly higher BGP and PICP, and lower CTX-1, compared with the T-plate group (P<0.05; **Figure 3**).

Representative cases

As shown in **Figure 4A**, **4B**, a male patient presented with a closed Edinburgh type 1B2 fracture of the right proximal clavicle, which was stabilized with two mini-plate fixation. Preoperative computed tomography (CT) scans revealed a displaced proximal clavicular fracture. A six-month postoperative anteroposterior X-ray demonstrated complete fracture union and stable internal fixation.

In **Figure 4C**, **4D**, another male patient exhibited a closed Edinburgh type 1B1 fracture of the left distal clavicle, managed with a T-plate fixation. Preoperative CT images confirmed fracture displacement, while radiographs obtained

Table 3. Comparison of surgical-related indices between the two groups

Variable	Mini-plate group (n=57)	T-plate group (n=43)	t	P
Operation duration (min)	55.65±9.80	57.58±6.61	1.114	0.268
Incision length (cm)	3.89±1.01	5.93±1.10	9.623	<0.001
Intraoperative blood loss (mL)	25.30±10.34	27.42±8.62	1.089	0.279

Table 4. Comparison of postoperative rehabilitation parameters between the two groups

Variable	Mini-plate group (n=57)	T-plate group (n=43)	t	P
Hospitalization length (d)	10.652.54	11.88±3.19	2.147	0.034
Fracture healing time (months)	5.68±2.11	6.60±2.23	2.106	0.038
Time to return to work (weeks)	7.21±2.65	8.63±2.81	2.585	0.011

Table 5. Comparison of postoperative complications between the two groups

Variable	Mini-plate group (n=57)	T-plate group (n=43)	χ^2	P
Internal fixation loosening	2 (3.51)	6 (13.95)		
Surgical site infection	1 (1.75)	3 (6.98)		
Infraclavicular brachial plexus irritation	2 (3.51)	3 (6.98)		
Shoulder stiffness	2 (3.51)	4 (9.30)		
Total	7 (12.28)	16 (37.21)	8.600	0.003

Table 6. Comparison of VAS scores between the two groups

	Mini-plate group (n=57)	T-plate group (n=43)	t	P
Before surgery	4.88±2.22	5.51±1.72	1.543	0.126
2 weeks after surgery	3.21±1.78^{a}	4.14±2.12^{a}	2.382	0.019
1 month after surgery	2.35±1.13^{a,b}	3.51±1.56^{a,b}	4.313	<0.001
3 months after surgery	1.11±0.75^{a,b,c}	1.79±0.91^{a,b,c}	4.094	<0.001

Note: VAS, Visual Analogue Scale. ^{a}P<0.05, vs. preoperative; ^{b}P<0.05, vs. 2-week postoperative; ^{c}P<0.05, vs. 1-month postoperative.

at six months post-surgery indicated satisfactory bone healing and properly aligned hardware.

Discussion

Clinically, displaced proximal clavicle fractures (PCFs) are primarily caused by high-energy trauma transmitted either directly or indirectly to the medial clavicle [19]. Direct injury involves a force acting straight on the clavicular head, resulting in fracture, whereas indirect injury occurs when force is transmitted from the shoulder girdle toward the medial clavicle, also leading to fractures. Biomechanically, PCFs are highly unstable due to the combined influence of the sternocleidomastoid muscle traction, the weight of the upper limbs, and the pull of the pectoralis major muscle [20]. In cases with obvious displacement, conservative treatment often fails to achieve satisfactory reduction or stable fixation, predisposing patients to chronic pain, nonunion, and shoulder joint dysfunction [21]. Consequently, prompt surgical treatment is now increasingly advocated for severely displaced PCFs, particularly in patients with high functional demands, while also considering patient age, occupation, and overall health status. This study comparatively analyzes the clinical efficacy of two internal fixation methods in markedly displaced PCFs, aiming to identify the more effective fixation strategy for optimizing surgical efficiency, reducing surgical risks, and minimizing postoperative complications, thereby providing evidence-based guidance for clinical practice.

This study demonstrated a higher clinical efficacy rate offered by dual mini-plate fixation than by T-plate internal fixation (91.23% vs. 74.42%). In the management of PCF, T-plate fixation simplifies surgery by minimizing sternoclavicular joint exposure while exerting minimal impact on the surrounding blood supply; moreover, multiple screw placement enhances fixa-

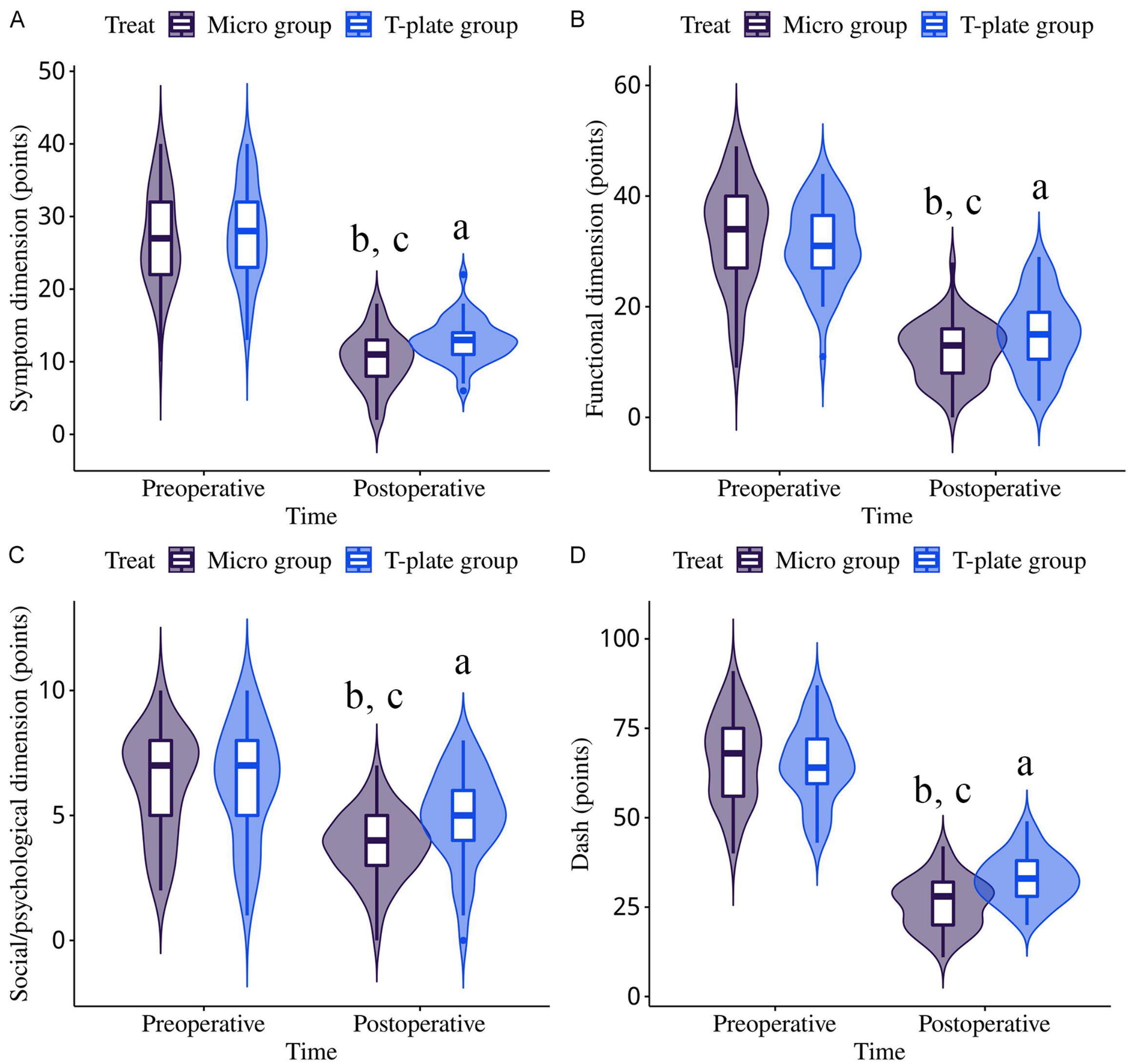

Figure 1. Comparison of DASH score between two groups before and after the treatment. A. symptom dimension scores. B. Functional dimension scores. C. Social/psychological dimension scores. D. Total DASH scores. Note: DASH, Disabilities of the Arm, Shoulder, and Hand. [a]P<0.05, [b]P<0.01, vs. preoperative; [c]P<0.05, vs. T-plate group at same time point.

tion strength and reduces the risks of mechanical failure [22]. In contrast, dual mini-plates typically involves positioning two plates orthogonally - one on the anterior and the other on the superior surface of the clavicle - a 90-degree configuration. By angling screws in varying orientations, stable fixation is ensured, which enhances internal fixation effectiveness and notably lowers reduction failure risks, thus optimizing union outcomes [23]. Despite the comparable operative time and intraoperative blood loss between the two methods, the mini-plate fixation was associated with a smaller surgical incision. Regarding postoperative rehabilitation, dual mini-plate fixation was obviously advantageous over T-plate internal fixation in shortening hospitalization, facilitating fracture healing, accelerating postoperative work resumption, and expediting postoperative rehabilitation. In the study of Ma C et al. [24], the application of dual mini-plate fixation in Edinburgh IB PCF patients effectively shortened incision length, promoted postoperative recovery, and reduced medical costs, supporting the conclusions in this study.

In the safety analysis, patients who underwent dual mini-plate fixation exhibited an obviously lower overall incidence of internal fixation loosening, surgical site infection, infraclavicular bra-

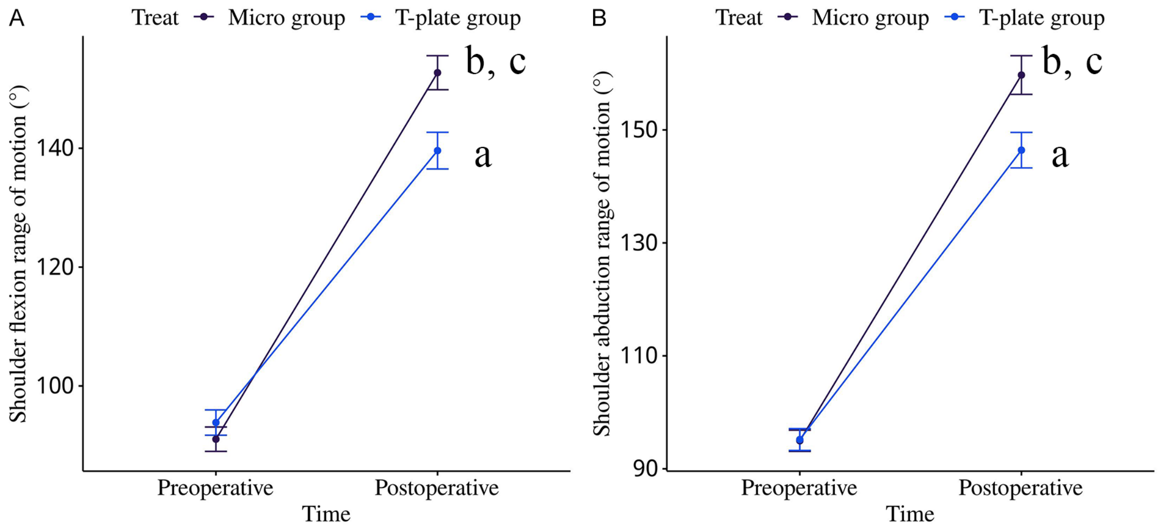

Figure 2. Comparison of shoulder joint mobility between the two groups before and after treatment. A. Shoulder flexion range. B. Shoulder abduction range. Note: [a]P<0.05, [b]P<0.01, vs. preoperative; [c]P<0.05, vs. T-plate group at same time point.

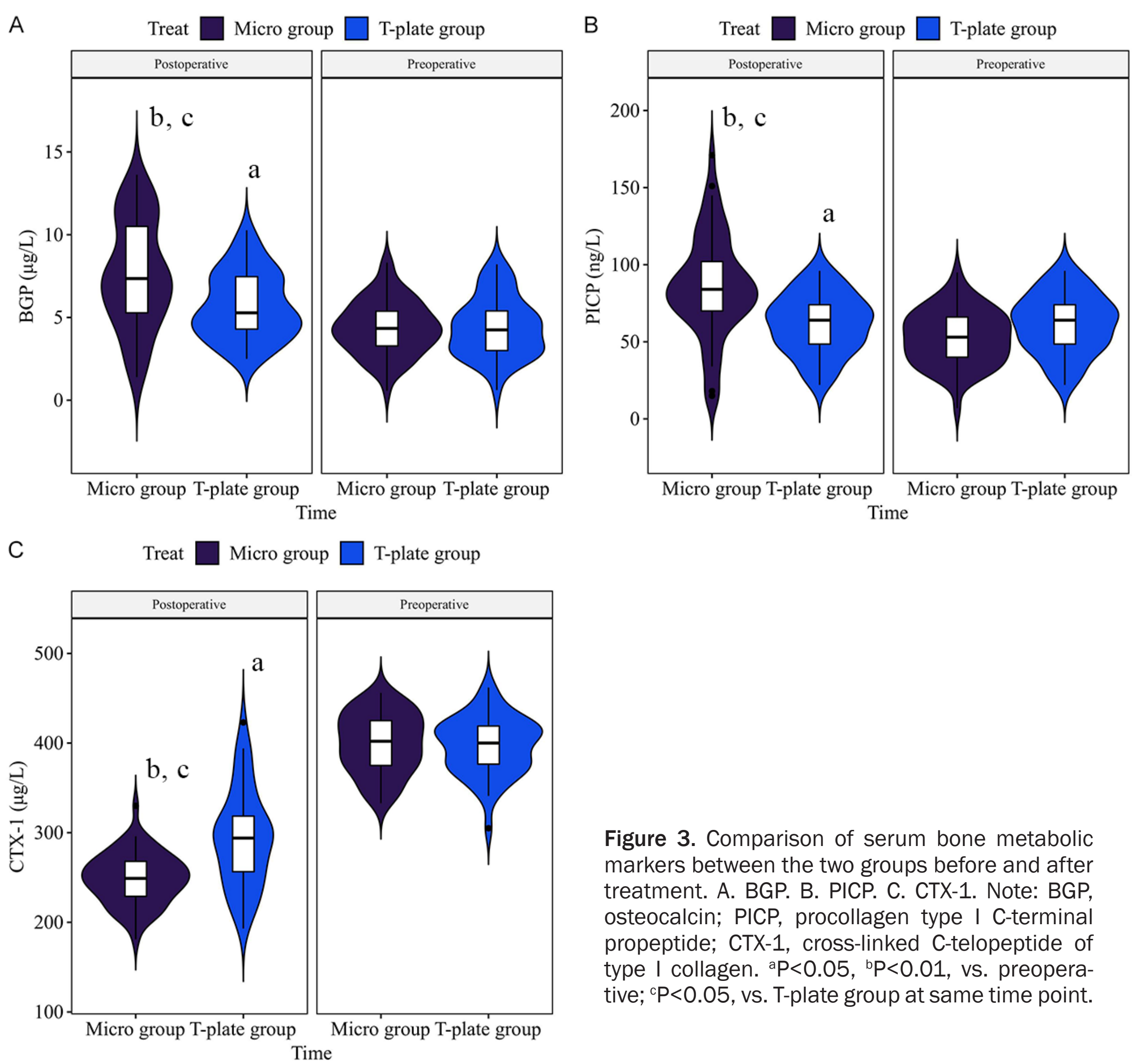

Figure 3. Comparison of serum bone metabolic markers between the two groups before and after treatment. A. BGP. B. PICP. C. CTX-1. Note: BGP, osteocalcin; PICP, procollagen type I C-terminal propeptide; CTX-1, cross-linked C-telopeptide of type I collagen. [a]P<0.05, [b]P<0.01, vs. preoperative; [c]P<0.05, vs. T-plate group at same time point.

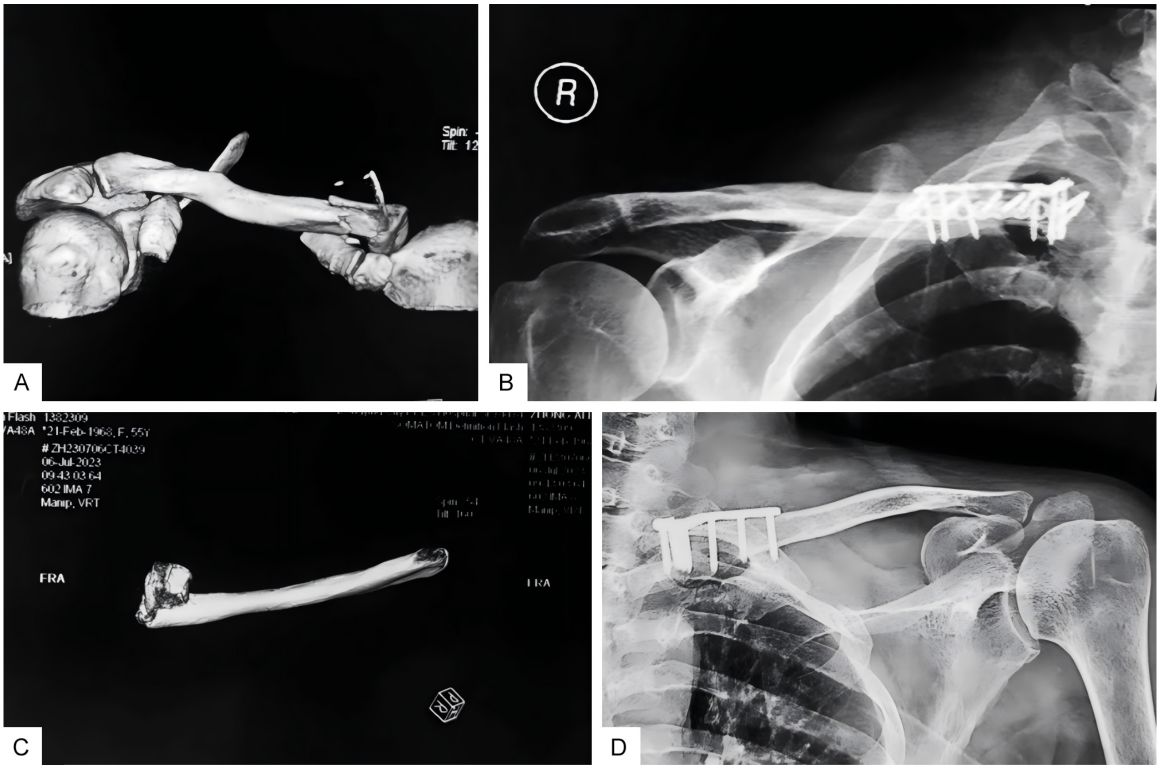

Figure 4. Typical cases in two groups. A. Preoperative CT scan showing a displaced fracture of the proximal clavicle. B. Anteroposterior clavicular X-ray obtained six months postoperatively demonstrating complete osseous union and stable internal fixation. C. Preoperative CT scan revealing a displaced clavicular fracture. D. X-ray obtained at six months post-operation showing fracture healing and satisfactory internal fixation Note: CT, computed tomography.

chial plexus irritation, and shoulder stiffness. Similarly, Xu et al. [25] reported that although the two fixation techniques showed comparable operative duration and preoperative blood loss, dual mini-plate fixation accelerated fracture healing by reducing postoperative complications, findings consistent with our observations.

Furthermore, DASH and VAS scores at multiple postoperative time points (2 weeks, 1 month, and 3 months) demonstrated superior pain relief and functional recovery in patients treated with dual mini-plate fixation. Srivastava et al. [26] reported that the application of double Y-shaped titanium mini-plates for mandibular fractures demonstrated enhanced pain reduction at the 6-month follow-up compared with traditional plate-and-screw constructs, supporting the notion that dual-plate configurations may offer improved and sustained pain relief.

In addition, dual mini-plate fixation for Edinburgh IB PCFs significantly improved the shoulder flexion and abduction ROM, while validly modulating serum bone metabolism markers, as evidenced by increased BGP and PICP levels and decreased CTX-1 concentrations. Similarly, Eden et al. [27] demonstrated that dual-plate fixation in Monteggia-like lesions improved shoulder flexion ROM, corroborating our findings. Bone metabolic markers have been shown to correlate closely with the progression and healing of Edinburgh type IB PCFs [28]. Clinically, BGP plays a critical role in bone matrix mineralization, while PICP reflects bone microstructure integrity; conversely, CTX-1 serves as a bone resorption indicator. Monitoring the dynamic changes in these factors provides insight into the balance between osteogenesis and osteolysis during fracture healing [29, 30]. Collectively, dual mini-plate fixation effectively restores bone metabolic equilibrium in patients with Edinburgh IB PCFs, evidenced by enhanced bone formation and diminished bone absorption.

The surgical procedure discussed in this study requires several key considerations: Fracture exposure should proceed in an anteroposterior direction, maintaining close contact with the periosteum during subperiosteal dissection to conform with the principles of the Arbeitsgemeinschaft für Osteosynthesefragen (AO) and Biological Osteosynthesis (BO). When implanting the anterior clavicular mini-plate, depth-restricted drill sleeves should be employed to prevent excessive penetration during drilling. Screw length should be carefully measured using a depth probe with controlled pressure, ensuring accurate sizing and stable fixation. During screw insertion, appropriate screw selection is critical, and a periosteal elevator can be used posteriorly to protect underlying neurovascular structures. In cases with small or comminuted fractured fragments, temporary stabilization using absorbable suture ligation or K-wire fixation can be employed to maintain anatomical reduction and prevent clavicular shortening or malalignment.

Several limitations of this study should be acknowledged. First, the sample size was relatively small and derived from a single center, which may introduce selection bias. Utilizing larger, multi-center cohorts are warranted to enhance the generalizability and robustness of the findings. Second, the absence of long-term follow-up data beyond five years limits the assessment of the durability and late outcomes of dual mini-plate fixation. Finally, the economic implications of both techniques were not analyzed. Future investigations incorporating cost-benefit evaluations would provide valuable insights into the overall clinical and economic advantages of dual mini-plate fixation.

Conclusion

Dual mini-plate fixation for Edinburgh IB PCFs demonstrates superior clinical efficacy compared with T-plate fixation. It effectively reduces surgical incision length, accelerates postoperative recovery and functional rehabilitation, and lowers overall complication rates. Furthermore, it contributes to significant pain reduction, improved shoulder mobility, and favorable modulation of bone metabolism, underscoring its value as a safe and efficient fixation strategy for displaced proximal clavicle fractures.

Disclosure of conflict of interest

None.

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