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Comparison of biomechanical stability between tension band wiring and a 6.5-mm intramedullary screw fixation after chevron olecranon osteotomy: A cadaveric ulna study

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Abstract

Chevron olecranon osteotomy is widely used to expose distal humerus fractures. Optimal fixation is essential to maintain joint stability and allow early mobilization. Tension Band Wiring (TBW) remains the most commonly used technique but is associated with complications including wire migration and soft-tissue irritation. Intramedullary fixation using a 6.5-mm screw has emerged as a simpler alternative, although comparative biomechanical evidence remains limited. To compare the biomechanical stability of tension band wiring versus 6.5-mm intramedullary screw fixation following Chevron olecranon osteotomy in cadaveric ulna. Fourteen formalin-preserved cadaveric ulna were randomly divided into two groups: TBW fixation (n = 7) and intramedullary screw fixation (n = 7). All specimens underwent standardized Chevron osteotomy and were subjected to cyclic traction loading of 200 N to simulate triceps pull. Fragment displacement was measured at the 10th, 20th, and 50th cycles using digital calipers. Statistical analysis was performed using Mann–Whitney U test ($\alpha = 0.05$). The TBW group demonstrated significantly lower displacement across all loading cycles. At the 50th cycle, median displacement was 0.1901 cm in the TBW group versus 0.3651 cm in the screw group ($p < 0.001$). Progressive displacement increase was consistently greater in the intramedullary screw group. Tension band wiring provides superior biomechanical stability compared with 6.5-mm intramedullary screw fixation in cadaveric Chevron olecranon osteotomy under cyclic loading. Although intramedullary screw fixation may offer clinical advantages such as reduced implant prominence, its lower resistance to repetitive traction suggests it may be less suitable for high-demand or early-mobilization cases.

Keywords: Olecranon osteotomy, Chevron osteotomy, Tension band wiring, Intramedullary screw, Biomechanical testing, Cadaver study

Introduction

Distal humerus fractures account for approximately 2% of all adult fractures and require anatomical reduction and stable fixation to restore elbow function. Posterior surgical exposure via Chevron olecranon osteotomy offers excellent visualization of the articular surface and columns but necessitates reliable fixation to prevent displacement, non-union, or loss of extension strength[1-6].

Tension Band Wiring (TBW) remains the standard fixation method because it converts tensile forces from triceps contraction into dynamic compression at the articular surface. However, TBW is associated with frequent hardware complications, with irritation and wire migration reported in up to 80% of cases. Intramedullary screw fixation has been proposed as an alternative that minimizes hardware prominence and reduces soft-tissue irritation, yet biomechanical validation remains limited[1-6].

This study evaluates whether a single 6.5-mm intramedullary screw can provide biomechanical stability comparable to TBW under cyclic triceps loading in a laboratory model of Chevron osteotomy.

Methods

Study design

Experimental in-vitro biomechanical study using a post-test only randomized group design.

Specimens

Fourteen male cadaveric ulna (age 20–60 years, preserved <3 years in 10% formalin) were obtained from the Anatomy Laboratory, Faculty of Medicine, Universitas Airlangga. Specimens with pre-existing deformity, fracture, or gross cortical damage were excluded.

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Groups

Group	Fixation Method	n
P1	Tension Band Wiring (TBW)	7
P2	Intramedullary Screw 6.5 mm	7

Osteotomy technique

A standard Chevron osteotomy (apex distal) was created using oscillating saw and completed manually to preserve surface interdigitation.

Fixation techniques

- **TBW:** Two parallel 1.6-mm K-wires inserted bicortically, combined with 1.0-mm stainless loop wire in figure-of-eight configuration.
- **Intramedullary screw:** One 6.5-mm partially threaded cannulated screw inserted from olecranon tip to distal cortical engagement.

Biomechanical testing

- Tensile loading applied via a 200-N traction force using servo-hydraulic testing machine.
- Simulated cyclic triceps contraction: 50 consecutive pull cycles.
- Displacement between proximal and distal fragments recorded at cycles 10, 20, and 50.

Statistical analysis

Data were non-parametric; Mann–Whitney U test used to compare groups across cycles. Significance set at $p < 0.05$.

Results

Fourteen human cadaveric ulnae that met the inclusion and exclusion criteria were included in this study. All specimens were obtained from male donors aged 20–60 years, preserved in 10% formalin, and cleared of soft tissues. Samples were randomly divided into two groups: Tension Band Wiring (TBW, n = 7) and 6.5-mm Intramedullary Screw (IMS, n = 7) fixation.

Each ulna underwent Chevron olecranon osteotomy followed by cyclic triceps traction using a Shimadzu AG-10 TE universal testing machine. A 200 N load was applied at a constant rate of 10 mm/min, simulating repetitive triceps tension during elbow movement. Displacement between proximal and distal fragments was recorded using a digital caliper at the 10th, 20th, and 50th loading cycles.

Normality of data was verified using the Shapiro–Wilk test, and homogeneity of variance was confirmed with Levene's test ($p = 0.694$). Because the IMS group did not meet normality assumptions at all cycles, the Mann–Whitney U test was used for group comparisons.

Mean and median displacement values for each fixation type are summarized in Table 1. Across all loading cycles, the TBW construct consistently demonstrated lower displacement than IMS, indicating superior mechanical stability. At the 10th cycle, mean displacement was 0.136 ± 0.010 cm for TBW versus 0.306 ± 0.008 cm for IMS ($p < 0.001$). After 50 loading cycles, displacement increased to 0.178 ± 0.029 cm (TBW) and 0.346 ± 0.028 cm (IMS), with all differences remaining statistically significant ($p < 0.001$).

Because only two groups were compared, post-hoc analysis was not required. The Mann–Whitney U test alone was sufficient to confirm that fixation with TBW and IMS produced significantly different fragment displacements under cyclic loading.

Table 1. Comparison of displacement values between Tension Band Wiring (TBW) and Intramedullary Screw (IMS) fixation under cyclic triceps loading.

Cycle	Fixation Type	Mean ± SD (cm)	Median (Min–Max)	p-value
10×	TBW	0.136 ± 0.010	0.138 (0.123–0.153)	< 0.001
	IMS	0.306 ± 0.008	0.308 (0.293–0.314)	
20×	TBW	0.148 ± 0.015	0.153 (0.123–0.178)	< 0.001
	IMS	0.321 ± 0.017	0.323 (0.293–0.343)	
50×	TBW	0.178 ± 0.029	0.190 (0.123–0.214)	< 0.001
	IMS	0.346 ± 0.028	0.365 (0.293–0.379)	

Both fixation constructs exhibited progressive increases in displacement with repeated loading; however, the rate of increase was significantly lower in the TBW group (Figure 1).

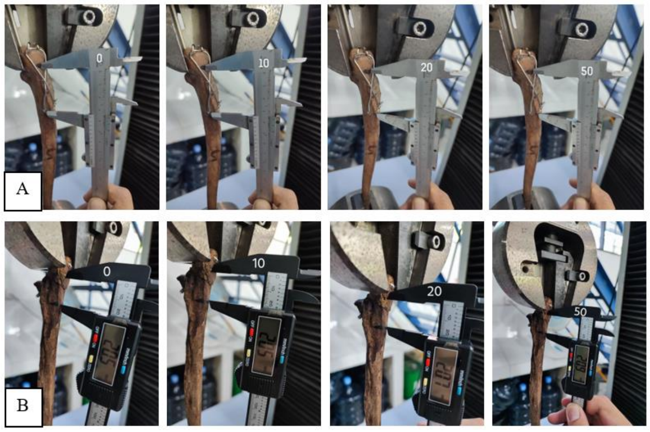

Figure 1. Progressive displacement of Tension Band Wiring (TBW) and Intramedullary Screw (IMS) constructs under cyclic triceps loading (10×, 20×, 50×)

Fig 1. Displacement measurement of olecranon osteotomy fixation under cyclic triceps loading using the Shimadzu AG-10TE universal testing machine. (A) Specimens fixed with Tension Band Wiring (TBW) at 0, 10, 20, and 50 loading cycles. (B) Specimens fixed with 6.5-mm Intramedullary Screw (IMS) at 0, 10, 20, and 50 loading cycles. Displacement between the proximal and distal osteotomy fragments was recorded using a digital or analog caliper positioned on the medial side of the ulna to measure separation during cyclic triceps traction at 200 N. Progressive fragment separation is observed with increasing loading cycles, demonstrating higher displacement in IMS compared to TBW constructs.

Overall, these results demonstrate that Tension Band Wiring provides greater biomechanical stability than a single 6.5-mm Intramedullary Screw for Chevron olecranon osteotomy fixation under simulated triceps traction.

Discussion

Distal humerus fractures remain one of the most technically demanding injuries in orthopaedic trauma due to the complex articular anatomy, limited bone stock, and frequent intra-articular comminution, especially in osteoporotic bone [7-9]. These fractures account for approximately 2% of all adult fractures and require anatomic reduction with stable fixation to restore elbow function and enable early mobilization[10]. The posterior approach through Chevron olecranon osteotomy remains the standard exposure for accurate visualization of the distal articular surface, but it introduces an additional osteotomy site that must be securely fixed to preserve triceps function[12-13].

The most widely used method for olecranon osteotomy fixation is Tension Band Wiring (TBW), introduced by Weber and Vasey in 1963[14]. TBW converts tensile forces generated by the triceps during elbow motion into compressive forces at the articular surface, promoting bone healing through dynamic compression. However, TBW is associated with potential complications, including wire migration, soft-tissue irritation, hardware prominence, and loss of reduction[15-17]. Despite these drawbacks, it remains the preferred method in many centers due to its biomechanical reliability and cost-effectiveness.

As an alternative, intramedullary screw fixation has gained attention for its simplicity and reduced soft-tissue irritation. Several studies have reported comparable or improved radiological outcomes and lower complication rates with intramedullary fixation compared with TBW[17-18]. The principle of this technique relies on axial interfragmentary compression along the ulna's long axis, which minimizes hardware prominence and decreases the risk of soft-tissue irritation. However, whether it provides equivalent mechanical stability under cyclic triceps loading remains uncertain.

In the present biomechanical study, both fixation methods exhibited progressive displacement with repeated loading, reflecting the cumulative effect of cyclic triceps traction. However, displacement values were consistently higher in the Intramedullary Screw (IMS) group than in the Tension Band Wiring (TBW) group at all cycles (10×, 20×, 50×), with statistically significant differences ($p < 0.001$). After 50 loading cycles, the mean displacement in the TBW group was 0.177 ± 0.029 cm, while that of the IMS group was 0.346 ± 0.028 cm, indicating nearly double the displacement in the screw fixation construct.

These findings support the biomechanical principle that TBW offers greater resistance to displacement by converting tensile triceps forces into compressive forces during elbow flexion[19]. In contrast, the intramedullary screw provides static axial compression but lacks the dynamic compressive effect generated by TBW. As a result, under cyclic or bending loads, IMS constructs may exhibit greater micromotion at the osteotomy interface, explaining the larger displacement observed in this study. Similar results were reported by Brink et al. (2013), who demonstrated that TBW provides higher stability under dynamic loading, and by Weber & Vasey (1963), who originally described the tension-band concept[13].

Clinically, these findings are consistent with previous reports indicating that TBW fixation allows earlier functional rehabilitation and lower risk of displacement compared with single-screw fixation. Hume and Wiss (1992) and Hewins et al. (2007) both reported satisfactory outcomes using intramedullary screws, but their evaluations were primarily based on radiologic union and soft-tissue tolerance rather than cyclic biomechanical stability. While screw fixation offers advantages in reducing hardware prominence and postoperative irritation, its biomechanical resistance to dynamic triceps traction may be inferior to TBW in situations requiring early motion or high flexion stress[6,17-18].

The present study therefore reinforces the role of TBW as a biomechanically stronger construct in Chevron olecranon osteotomy fixation. Nevertheless, the potential clinical advantages of intramedullary screw fixation such as simplified technique, lower hardware irritation, and satisfactory bone union should not be overlooked. The choice of fixation should consider patient-specific factors, including bone quality, soft-tissue condition, and the need for early mobilization.

Study limitations

This study has several limitations. First, it was conducted on formalin-preserved cadaveric ulnae, which may not perfectly replicate the viscoelastic properties of living bone. Second, only a single screw size (6.5 mm) was evaluated; variations in screw design, thread pitch, or use of washer could affect stability. Third, the cyclic loading conditions simulated triceps traction but did not include complex multidirectional forces encountered in vivo. Despite these limitations, the results provide meaningful comparative data under controlled laboratory conditions.

Clinical relevance

In clinical practice, olecranon osteotomy remains an essential approach for distal humerus fracture fixation. The results of this study suggest that Tension Band Wiring provides superior biomechanical stability under cyclic triceps loading compared with intramedullary screw fixation, supporting its continued use when early elbow motion is required. Intramedullary screw fixation may remain a reasonable alternative in cases prioritizing reduced soft-tissue irritation or when dynamic flexion stresses are minimal.

Conclusion

This biomechanical study demonstrated that Tension Band Wiring (TBW) provides significantly greater stability than a single 6.5-mm Intramedullary Screw (IMS) for fixation of Chevron olecranon osteotomy under cyclic triceps loading. Across all loading cycles, TBW consistently showed lower displacement values ($p < 0.001$), indicating superior resistance to repetitive traction and bending forces. The dynamic compression mechanism of TBW, which converts triceps tensile forces into articular compression during elbow motion, contributes to its superior stability compared to the static axial compression provided by intramedullary screw fixation. While intramedullary screw fixation offers advantages in reducing soft-tissue irritation, simplifying the surgical technique, and maintaining satisfactory union rates, it produces greater fragment displacement under repetitive load. Therefore, TBW remains the more biomechanically stable option for olecranon osteotomy fixation, especially in cases requiring early mobilization or high flexion stress. Further clinical and biomechanical studies using fresh-frozen specimens, different screw configurations, and multidirectional loading models are recommended to validate these findings and optimize fixation strategies for distal humerus exposure and reconstruction.

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