Can Intramedullary Screws Stabilize Very Proximal Metacarpal Base Fractures? A Cadaveric Biomechanical Analysis

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INTRODUCTION: Intramedullary threaded nail fixation has shown promising biomechanical and clinical outcomes in the management of metacarpal shaft and neck fractures. Extraarticular fractures at the metacarpal base, while common, remain underrepresented in biomechanical research. Although limited clinical studies suggest superior outcomes for intramedullary screw over plating in this fracture pattern, these studies often involve small sample sizes and lack biomechanical validation. To date, no biomechanical studies have evaluated the proximal limit of fracture stabilization achievable with intramedullary threaded nails.

METHODS:

In this biomechanical study, 36 cadaveric metacarpals (index, middle, and ring fingers) from 12 upper extremities were used to determine the most proximal location at which intramedullary (IM) threaded screws can effectively stabilize extraarticular base fractures. Metacarpals were skeletonized, measured, and marked at 10%, 20%, and 30% of total length from the proximal aspect, then potted distally in cement. Standardized transverse fractures were created at each location using an oscillating saw. Specimens were fixed with IM headless screws placed antegrade and buried below the articular surface (Figure 1). Cantilever bending tests were performed using MTS machine at a loading rate of 0.3 mm/s (Figure 2). Primary and secondary outcomes were ultimate failure load and construct stiffness, respectively.

RESULTS:

A total of 36 cadaveric metacarpals (12 each of index, middle, and ring fingers) were randomized to undergo simulated transverse fractures at 10%, 20%, or 30% of total metacarpal length from the distal aspect (n = 12 per location). Biomechanical testing revealed that intramedullary (IM) screw fixation provided the highest ultimate failure load at the 10% fracture location (mean 190.45 N), followed by 30% (166.77 N) and 20% (142.16 N). For the middle finger, this trend was consistent, while in the index finger, the 30% fracture had the highest load to failure, followed by 10% and 20%. For the ring finger, the 10% location demonstrated the greatest strength (135.82 N), with decreasing values at 20% (116.16 N) and 30% (96.75 N) (Table 1). Statistically significant differences in failure load were observed at the 10% fracture location when comparing the index and middle fingers to the ring finger (213.81 N and 221.42 N vs. 135.82 N, $p < 0.05$).

DISCUSSION AND CONCLUSION:

Intramedullary screw fixation can effectively stabilize extraarticular metacarpal base fractures as proximal as 10% of total metacarpal length, with biomechanical strength sufficient to support early mobilization protocols. The highest failure loads were observed at the 10% fracture location, particularly in the index and middle metacarpals, suggesting reliable fixation even in very proximal shaft fractures.

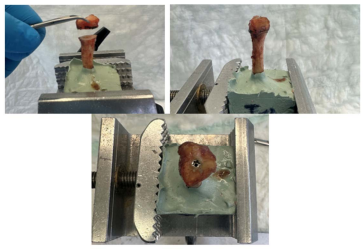

Figure 1: Experimental setup demonstrating sample preparation. Top left: simulated fracture at 10% of metacarpal length. Top right: intramedullary screw fixation viewed laterally. Bottom: top-down view of the intramedullary fixation.

Table 1: Primary and secondary biomechanical outcomes stratified by fracture location and metacarpal type.

	Fracture Length (%)			
All Metacarpals	10 (N=12)	20 (N=12)	30 (N=12)	P-value
Load To Failure (N), mean ± SD	190.35 ± 70.00[a]	142.16 ± 43.17[a]	166.77 ± 77.92[a]	0.326
Stiffness (N/mm), mean ± SD	13.63 ± 8.16[a]	13.78 ± 7.06[a]	20.16 ± 11.31[a]	0.145
Index Metacarpals	(N=4)	(N=4)	(N=4)	
Load To Failure (N), mean ± SD	213.81 ± 96.88[a]	139.96 ± 29.42[a]	217.08 ± 123.58[a]	0.370
Stiffness (N/mm), mean ± SD	11.14 ± 5.32[a]	12.83 ± 5.23[a]	20.21 ± 3.32[a]	0.114
Middle Metacarpals	(N=4)	(N=4)	(N=4)	
Load To Failure (N), mean ± SD	221.42 ± 47.13[a]	170.12 ± 62.24[a]	189.58 ± 96.44[a]	0.480
Stiffness (N/mm), mean ± SD	18.56 ± 9.47[a]	16.95 ± 8.35[a]	21.83 ± 17.20[a]	0.864
Ring Metacarpals	(N=4)	(N=4)	(N=4)	
Load To Failure (N), mean ± SD	135.82 ± 19.36[a]	116.39 ± 12.66[a]	96.75 ± 78.85[a]	0.212
Stiffness (N/mm), mean ± SD	11.20 ± 8.82[a]	11.55 ± 8.03[a]	18.45 ± 12.43[a]	0.840

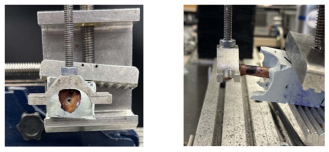

Figure 2: Biomechanical testing setup using the MTS machine. Right: frontal view showing intramedullary screw fixation. Left: lateral view demonstrating cantilever loading applied specifically to the fractured segment.