Metatarsophalangeal Joint Distraction as a Basis for Radiographic and Ultrasonographic Diagnosis of Plantar Plate Tear; A Cadaveric Study

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[1]Foot and Ankle

INTRODUCTION: Plantar plate (PP) tear is a common cause of metatarsophalangeal (MTP) joint instability, frequently resulting in forefoot pain and progressive deformity. Accurate and early diagnosis is essential for effective treatment. This cadaver study aims to identify reliable radiographic and ultrasonographic measurements of MTP joint instability under axial traction stress.

METHODS: Twenty-six MTP joints from fresh-frozen cadaveric specimens were used for radiographic analysis, and nineteen for ultrasonographic evaluation, to assess joint instability under intact, partial, and complete plantar plate tear conditions. MTP joint widening was measured using radiographic and ultrasonographic imaging under four levels of axial traction force (0 N, 25 N, 50 N, and 75 N), applied at both neutral and 40-degree dorsiflexed MTP positions. Joint space widening was compared across all conditions. Receiver operating characteristic (ROC) curve analysis was performed to determine clinically relevant cutoff values. Statistical significance was defined as $p < 0.05$.

RESULTS:

At the neutral MTP position, significant joint widening was observed on radiographic images under 25 N of axial traction when compared to the intact state ($p < 0.0001$ for complete tears; $p = 0.048$ for partial tears). In ultrasonographic images, significant widening occurred at 50 N in both partial (30% increase, $p = 0.01$) and complete tears (52% increase, $p < 0.001$). Application of a 25 N force led to a significant increase in MTP joint displacement across all plantar plate tear conditions, in both neutral and dorsiflexed MTP positions, as seen on both radiographic and ultrasonographic imaging.

For complete plantar plate tears, the radiographic cutoff for MTP joint widening was 5.3 mm, demonstrating excellent sensitivity of 92% and specificity of 86%. In ultrasonographic evaluation, 25 N of traction was effective for diagnosing complete tears in dorsiflexion, with an AUC of 0.87, a cutoff value of 7.2 mm, sensitivity of 0.82, and specificity of 0.83.

DISCUSSION AND CONCLUSION: This study demonstrated that MTP distraction measurement under 25 N of axial traction, could serve as a highly accurate quantitative diagnostic tool for complete plantar plate tears when assessed radiographically, with slightly lower accuracy using ultrasonography. However, diagnostic accuracy is reduced in cases of partial tears. Our results can help clinicians detect MTP instability and also guide them towards distinguishing partial versus complete plantar tears quantitatively using non-invasive and low to no-radiation imaging methods.

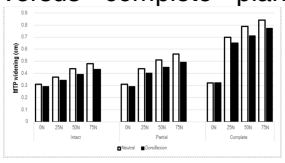


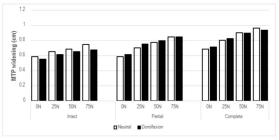
Figure 2: Effect of plantar plate-force on MTP widening in neutral and 40° dorsiflexion

Table 1: Mean MTP Joint Widening (± SD) in cm across Plantar Plate Conditions and MTP Alignments

	Intact PP		Partially tear PP		Completely tear PP		P value	
Force	Neutral	40 Dorsiflexion	Neutral	40 Dorsiflexion	Neutral	40 Dorsiflexion	Neutral	40 Dorsiflexion
0 N	0.58 (±0.11)	0.55 (±0.10)	0.58 (±0.12)	0.61 (±0.17)	0.68 (±0.14)	0.71 (±0.10)	0.98[a] 0.10[b]	0.25[a] 0.01[b]
25 N	0.65 (±0.11)	0.61 (±0.11)	0.70 (±0.09)	0.75 (±0.14)	0.80 (±0.11)	0.82 (±0.13)	0.15[a] 0.002[b]	0.01[a] < 0.0001[b]
50 N	0.68 (±0.12)	0.65 (±0.19)	0.77 (±0.11)	0.79 (±0.15)	0.90 (±0.14)	0.89 (±0.09)	0.02[a] < 0.0001[b]	0.007[a] < 0.0001[b]
75 N	0.74 (±0.13)	0.67 (±0.21)	0.84 (±0.13)	0.84 (±0.17)	0.96 (±0.15)	0.93 (±0.10)	0.01[a] < 0.0001[b]	0.002[a] < 0.0001[b]

[a] Intact vs Partial tear

[b] Intact vs Complete tear



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	Intact PP		Partially tear PP		Completely tear PP		P value	
Force	Neutral	40 Dorsiflexion	Neutral	40 Dorsiflexion	Neutral	40 Dorsiflexion	Neutral	40 Dorsiflexion
0 N	0.31 (±0.08)	0.29 (±0.08)	0.31 (±0.09)	0.29 (±0.08)	0.32 (±0.10)	0.32 (±0.09)	0.95[a] 0.89[b]	0.88[a] 045[b]
25 N	0.37 (±0.09)	0.34 (±0.09)	0.44 (±0.10)	0.40 (±0.10)	0.70 (±0.17)	0.65 (±0.16)	0.048[a] < 0.0001[b]	0.1[a] < 0.0001[b]
50 N	0.44 (±0.10)	0.39 (±0.10)	0.51 (±0.12)	0.45 (±0.11)	0.79 (±0.17)	0.71 (±0.16)	0.07[a] < 0.0001[b]	0.07[a] < 0.0001[b]
75 N	0.48 (±0.11)	0.43 (±0.11)	0.56 (±0.12)	0.49 (±0.12)	0.84 (±0.19)	0.77 (±0.17)	0.03[a] < 0.0001[b]	0.06[a] < 0.0001[b]

[a] Intact vs Partial tear

[b] Intact vs Complete tear