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Biomechanical Comparison of Fully-Threaded Solid Cortical versus Partially-Threaded Cannulated Cancellous Screw Fixation for the Treatment of Lisfranc Injuries

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Introduction

Lisfranc injuries are a frequent cause of patient morbidity, and if not treated with anatomic reduction and fixation, may lead to substantial pain, chronic instability, and arthritis. Several different screw designs can be readily employed in transarticular screw fixations of Lisfranc injuries, but the biomechanical differences between screws in this application are not well defined. This study sought to investigate the differences between fully-threaded solid cortical (FSC) screws and partially-threaded trabecular (PCT) bone screws in the milieu of a cadaveric model of a Lisfranc injury. The performance of the two screw types was quantified by measuring relative diastasis between surgically fixed bones within the midfoot. We hypothesized that there would be no significant differences in diastasis when comparing PCT and FSC screws.

In an effort to further characterize the biomechanical limits of the two screws, we executed several benchtop experiments to investigate relevant parameters of resistance to bending and pull-out strength. We hypothesized that the PCT screws would have lower ultimate failure and yield strength but higher pullout strength than FSC screws. It was further hypothesized that the loads at which these phenomena occur are substantially lower than those typically experienced during physiological loading in Lisfranc fixation.

Materials and Methods

Ten matched pairs of fresh frozen cadaveric feet were fused in 30° plantarflexion and tested in a universal testing frame (Figure 1A). 3-D locations of midfoot bones were recorded during static loading trials for healthy, injured, reconstructed, and cyclically loaded specimens with either fully-threaded solid cortical (FSC) or partially-threaded cannulated trabecular (PCT) bone screws. Diastasis between the first and second metatarsals and the medial and intermediate cuneiforms was measured and relative bony displacement was normalized to percentages for each specimen. Screws were retrieved after testing and subjected to three-point bending (Figure 1B) and pull-out tests (Figure 1C) to elucidate differences in relevant performance characteristics. One-tailed paired student's t-tests were used to evaluate the injuries applied to the specimens. For all other tests in this study, two-tailed, two-sample, equal variance t-tests were used with significance levels set at p=0.05.

Results

There were no significant differences between screw performances in the cadaveric model (Table 1). The mean normalized diastasis between medial and intermediate cuneiforms after reconstruction was 10.2 ± 11.5% and 6.2 ± 18.2% for FSC and PCT screws respectively ($p = 0.58$), while cycled specimens had mean values of 10.1 ± 17.9 % and 11.8 ± 12.9% ($p = 0.82$). Similarly, mean normalized distance between metatarsals after reconstruction was 2.0 ± 20.3% and 4.5 ± 10.5% for FSC and PCT screws ($p = 0.73$), and −0.7 ± 17.3% and 14.6 ± 24.6% for cycled specimens ($p = 0.15$). No screws were bent or loose when retrieved after

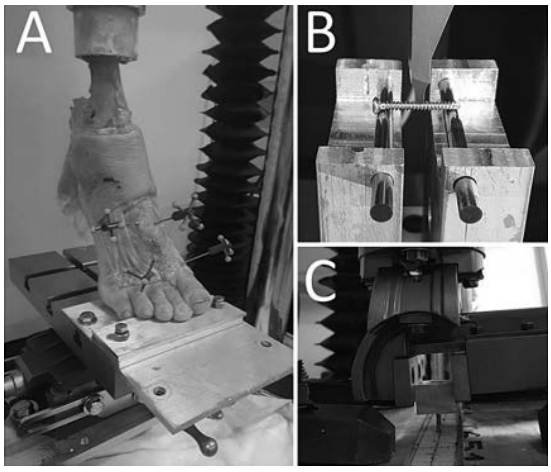

Figure 1. (A) Cadaveric testing positioned specimens in 30° plantarflexion and applied a static compressive load of 343N through the tibia. Relative diastasis of midfoot bones was tracked with 3-D motion tracking techniques. **(B)** Three-point bending tests were conducted to assess resistance to bending. **(C)** Screw pull-out tests were performed to quantify resistance to axial distraction loads.

Table 1. Comparisons of Diastasis Between Bones.

Group	n	Normalized Mean (%)	95% Confidence Interval	P-value
Healthy Cuneiform	20	0	0-0	0.003
Injured Cuneiform	20	12.2	3.7-20.8	
Reconstructed Solid Cuneiform	9	10.2	1.4-19.1	0.58
Reconstructed Cannulated Cuneiform	10	6.2	−6.8-19.2	
100 Cycles Solid Cuneiform	10	10.1	−2.7-23.0	0.82
100 Cycles Cannulated Cuneiform	9	11.8	1.9-21.7	
Healthy Metatarsal	18	0	0-0	0.03
Injured Metatarsal	18	8.4	−0.6-17.4	
Reconstructed Solid Metatarsal	10	2.0	−11.4-17.6	0.73
Reconstructed Cammlated Metatarsal	9	4.5	−2.1-14.I	
100 Cycles Solid Metatarsal	9	−0.7	−15.5-11.1	0.15
100 Cycles Cannulated Metatarsal	9	14.6	−9.7-28.2	

testing. Mean yield loads for FSC and PCT screws were 381.5 ± 15.6 and 375.7 ± 10.6 N ($p = 0.24$), respectively, while mean ultimate strengths were 570 ± 11.9 and 457.4 ± 6.7 N ($p<<0.001$), and ultimate pull-out loads were 121.8 ± 20.1 and 144.3 ± 13.1 N ($p = 0.001$).

Discussion & Conclusion

Results of this study suggest that FSC and PCT screws provide similarly suitable biomechanical stability in the physiologic milieu, despite their differences in failure mechanics. Given the wide variety of bony and or ligamentous patterns of disruption in these injuries, it is important to have multiple techniques in one's armamentarium to provide the patient with the best reconstructive option. In the future, a clinical follow-up study should be performed to confirm the findings of this in vitro investigation.

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