Biomechanical Comparison of First Metatarsophalangeal Joint Arthrodeses Using Triple-Threaded Headless Screws versus Partially Threaded Lag Screws

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Disclosures:

Introduction: First metatarsophalangeal joint (MTPJ-1) arthrodesis is indicated in patients with hallux rigidus, severe hallux valgus, or rheumatoid arthritis, among other severe disorders of the hallux, usually after nonsurgical therapies have been exhausted or other surgery has failed. Fusion of the MTPJ-1 is intended to provide relief of pain, restoration of function, correction of deformity, and/or stabilization of the joint. Arthrodesis is commonly performed using two crossed screws or a dorsal plate with a central screw across the MTPJ-1. Partially threaded, cannulated lag screws are a standard choice in MTPJ-1 arthrodesis. It is important to ensure that their threads cross the arthrodesis plane to achieve compression; however, that may not always be feasible as lag screw thread lengths are often limited to one or two options. A newly designed triple-threaded, cannulated headless screws and partially threaded cannulated lag screws in a cadaver model of MTPJ-1 arthrodesis. The null hypothesis was that there would be no differences found between the two types of screws in MTPJ-1 fixation. The alternate hypothesis was that the triple-threaded screws would provide greater failure strength and stiffness in first MTPJ-1 arthrodesis when compared with partially threaded lag screws.

Methods: Eleven paired specimens of preserved adult cadaver feet were obtained from a willed body program, mean age of 72.2 years (range, 56 to 92 years). The first ray was dissected out leaving only the metatarsal bone, proximal phalanx bone, sesamoid bones, MTPJ-1 capsule, and surrounding ligaments. One side of each matched pair was randomly selected to receive two 4.0-mm partially threaded, cannulated lag screws (OsteoMed, Addison, TX). The contralateral specimen received two 4.0-mm triple-threaded, cannulated headless screws (Small Bone Innovations, Morrisville, PA), Figure 1. The screws were implanted in a crossing pattern from a medial approach, fixing the joint at approximately 20° dorsiflexion and 15° valgus. For each specimen, the proximal metatarsal was potted into a 5.08-cm diameter polylvinyl chloride collar with polymethylmethacrylate, ensuring that the level of the cement was below the screw exit/entrance into the bone. The potted MTPJ-1 constructs were rigidly attached to the base of an MTS 858 Mini-Bionix materials testing system (MTS, Inc., Eden Prairie, MN) in a cantilever bending configuration. To measure displacement at the joint, a linear extensometer (MTS, Model 632.31F-24) was secured across the joint line with pins. A custom actuator tip applied dorsally directed bending to the center of the phalanx condyles at a rate of 2.0 mm/min until a distinct drop in load was observed or failure occurred. Load versus displacement curves were generated from the failure data of the MTPJ-1 arthrodesis constructs to determine bending displacement, failure load, and stiffness. Displacement at the joint and stiffness of the joint were determined from load versus extensometer displacement curves. The mode of failure for each construct was also recorded. Paired t-tests were performed for each variable with a significance level set at 0.05 to determine differences between the two arthrodesis constructs.

Results: Both constructs showed no differences in regard to bending displacement (p = 0.431), displacement at the joint (p = 0.597), or joint stiffness (p = 0.146). The triple-threaded screw construct sustained significantly higher failure load (124.94 ± 53.33 N) compared with the lag screw construct (96.45 ± 54.82 N), p = 0.040. It also achieved significantly higher bending stiffness (13.13 ± 6.15 N/mm versus 8.51 ± 5.03 N/mm), p = 0.017. None of the arthrodesis fixations of either construct failed at the joint line. In 10 specimens, the lag screw construct failed by disruption of the bone and screw contact either by stripping or compression of bone around the screw, while in the other there were signs of screw-to-screw contact resulting in screw bending. Disruption of the bone and screw purchase was also prominent in the triple-threaded construct (nine specimens), while bony fracture occurred in the metatarsal head (two specimens) and in the distal phalanx (one specimen).

Discussion: The results of this biomechanical study show that triple-threaded, cannulated headless screws displayed significantly greater bending stiffness and failure loads when compared with partially threaded, cannulated lag screws. There was no difference according to type of screw in bending displacement, joint displacement, or joint stiffness. Since both screw types were successful in limiting joint displacement in MTPJ-1 arthrodesis, the increased bending stiffness and load sustained by the triple-threaded constructs during failure may be attributed to design. Joint compression can be unsuccessful if the threading of a lag screw has purchase in both the metatarsal and proximal phalanx. The triple-threaded screws secure bony attachment on all sides of the joint with full threading, in addition to providing compression through the progressive thread pitch.

Significance: The results of this study show that MTPJ-1 arthrodesis constructs that employ either partially threaded lag screws
or triple-threaded headless screws provide more than adequate fusion at the joint with very little joint displacement even at high, dorsally directed loads. Significantly higher failure loads were sustained and significantly greater resistance to bending (stiffness) was achieved in the present study with use of the triple-threaded headless screws, which may be beneficial for patients at risk for increased MTPJ-1 stressing during bone consolidation. The greater fixation strength of triple-threaded headless screws suggests a viable alternative to conventional partially threaded lag screws in MTPJ-1 arthrodesis.

Acknowledgments:

References:

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