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Biomechanical comparison of first metatarsophalangeal joint arthrodeses using triple-threaded headless screws versus partially threaded lag screws

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ABSTRACT

Background: Triple-threaded, cannulated headless screws of varying thread diameters and pitch are designed to maintain thread length across the arthrodesis plane, provide joint compression, and reduce countersinking. This study tested the biomechanical fixation strength of conventional partially threaded lag screws compared to triple-threaded headless screws in first metatarsophalangeal joint arthrodesis.
Methods: First metatarsophalangeal joint arthrodesis using a crossed screw technique was performed on 11 paired, preserved cadaver first rays with two 4.0-mm triple-threaded, cannulated headless screws or two 4.0-mm partially threaded, cannulated lag screws. The constructs were tested to failure through dorsally directed cantilever bending.
Results: The triple-threaded, cannulated headless screws displayed significantly greater bending stiffness ($p = 0.017$) and failure load ($p = 0.040$) during load-to-failure testing compared to the partially threaded, cannulated lag screws.
Conclusions: Triple-threaded, cannulated headless screws may be a viable alternative to partially threaded lag screws in first metatarsophalangeal arthrodesis.

1. 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 [1–6]. Joint fixation techniques are varied and include the use of Kirschner wires, staples, plates, screws, intramedullary fixation, external fixation, and various combinations of these components [7–10]. Screw fixation has been shown to be biomechanically superior to wire fixation, but comparison studies evaluating achievement of fusion between the plate and the screw methods have yielded mixed results [2,8,9,11–13]. Clinically, two-screw techniques have been reported to have a fusion success rate of 91–100% [4,14,15]. Although there does not appear to be a clear consensus, it seems that MTPJ-1 arthrodesis is more commonly performed using two crossed screws or a dorsal plate with a central screw across the MTPJ-1. Joint preparation techniques for the MTPJ-1 are also variable and include planar cartilage excision by saw, simple cartilage debridement, cone and socket preparation, and machined conical reaming [16]. Cartilage debridement is preferred by some surgeons due to its simplicity. Others may prefer to implement a cup and cone reamer system that provides uniform cartilage removal in a ball and socket configuration.

Partially threaded, cannulated lag screws are a common choice in MTPJ-1 arthrodesis (Fig. 1, top) [8–10]. It is important to ensure that their threads cross the arthrodesis plane to achieve compression. An optimal lag screw would have threads that maximize screw purchase, but engage only the bone distal to the arthrodesis plane. However, that may not always be feasible as lag screw thread lengths are often limited to one or two options (commonly, 16 mm or 32 mm). Triple-threaded, cannulated headless screws (Fig. 1, bottom) with varying thread diameters and pitch may address this problem with continuous threads along the entire length of the screw. The central threads are progressive,

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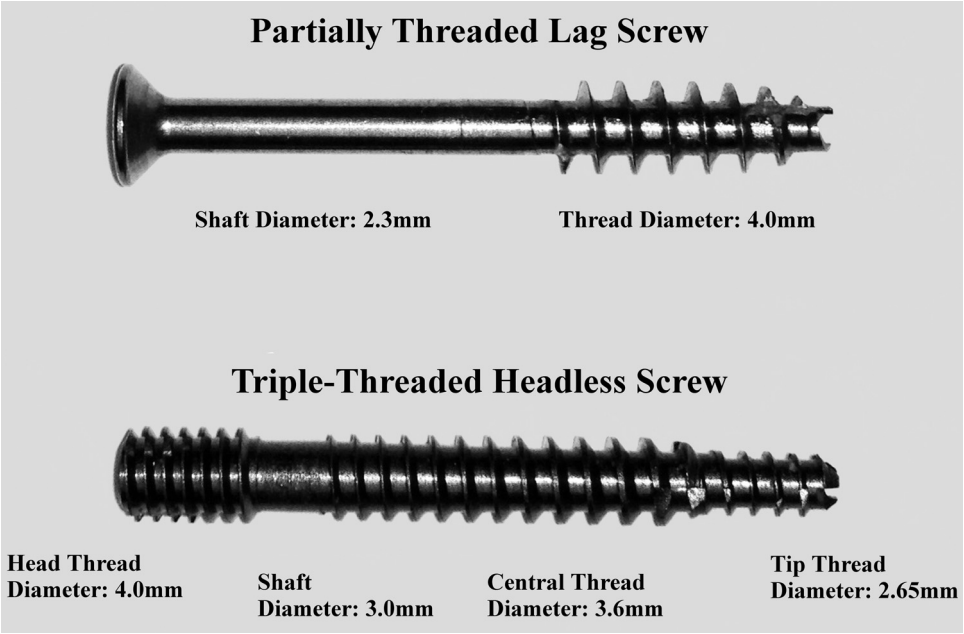

Fig. 1. Top, 4.0-mm partially threaded cannulated lag screw (OsteoMed, Addison, TX). Bottom, 4.0-mm triple-threaded cannulated headless screw (Small Bone Innovations, Morrisville, PA).

and may aid in fragment reduction due to the higher thread counts and provide "in situ" compression of the fragments [17,18]. This may ease implantation and alleviate a possible source of error during screw insertion. Additionally, headless screws require less countersinking and provide a lower profile, limiting contact with soft tissue that could be irritating.

This study compared biomechanical properties of 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 MTPJ-1 arthrodesis when compared with partially threaded lag screws.

2. Materials and methods

2.1. Specimens and MTPJ-1 arthrodesis

Thirteen paired specimens of preserved adult cadaver feet were obtained from a willed body program. The first ray was dissected from the feet leaving only the metatarsal bone, proximal phalanx bone, sesamoid bones, MTPJ-1 capsule, and surrounding ligaments. Each specimen was visually inspected to ensure that there were no deformities, fractures, or previous surgeries. One pair of specimens was discarded because of the presence of a fracture, and another because of a unilateral degenerative process. Of the remaining 11 pairs, five were from females and six from males, with a mean age of 72.2 years (range, 56–92 years).

For this study, the MTPJ-1 capsule was dissected to allow proximal phalanx and metatarsal articular cartilage removal. Cartilage removal was achieved through the use of a small round burr and a curette while maintaining the ball and socket conformation of the joint [4]. This method was chosen for its simplicity, that it maintains most of the natural joint line, and retains much of the soft tissue around the joint capsule. One Kirschner wire was inserted medially into the proximal phalanx and crossed the MTPJ-1 before exiting laterally out of the metatarsal. It was placed slightly dorsal to prevent interference with a second Kirschner wire that was inserted medially into the metatarsal. The second wire was implanted slightly plantar and exited the proximal phalanx laterally. The wires fixed the joint temporarily at approximately 20° dorsiflexion and 15° valgus as is recommended for MTPJ-1 arthrodesis [1,2,5,9]. These angles were produced using custom acrylic glass apparatuses with built-in angles and a goniometer for confirmation. Guide holes were also built into the apparatuses in order to standardize hole placement and angle of insertion among a matched pair. A length gauge was used to allow proper screw length selection and guide wire over drilling. Rather than standardizing the length of screws across all specimens, screw lengths were selected according to specimen size to best represent clinical arthrodesis.

One side of each matched pair was randomly selected to receive two 4.0-mm titanium partially threaded, cannulated lag screws (OsteoMed, Addison, TX). Overdrilling and countersinking were performed using the screw set's 3.0/4.0-mm cannulated drill bit and its 3.0/4.0-mm cannulated countersink bit. Appropriate length screws were then inserted medial to lateral over the previously inserted Kirschner wires by using a cannulated screwdriver. The contralateral specimen received two 4.0-mm titanium triple-threaded, cannulated headless screws (Small Bone Innovations, FusiFIX™, Morrisville, PA). The proximal, or head portion, of the screw is 4.0-mm in diameter, the central threading is 3.6-mm in diameter and progressive, with the distal threading measuring 2.65-mm. The screws used in this study were within ±2.0-mm in length of their partially threaded counterparts. The triple-threaded set's 4.0-mm cannulated drill bit and 4.0-mm cannulated countersink bit were used. Appropriate length triple-threaded screws were inserted in the same fashion as the partially threaded screws (Fig. 2).

2.2. Biomechanical testing and data analysis

The biomechanical protocol for this study was adapted from Neufeld et al. [9]. For each specimen, the proximal metatarsal was potted into a 2.0-inch (5.08-cm) diameter polyvinyl chloride collar with polymethylmethacrylate, up to the screw exit/entrance point into the bone. The potted MTPJ-1 constructs were rigidly attached to the base of an MTS 858 Mini-Bionix materials testing system