Effect of Intramedullary Tibial Nailing on Attachment Area and Ultimate Strength of the Anterior Medial Meniscal Root: Is the Safe Zone Really Safe?

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Introduction: Intramedullary (IM) nailing is the treatment of choice among orthopaedic surgeons for tibial shaft fractures, the most common of long bone fractures. In order to prevent iatrogenic damage to intra-articular structures during surgery, a “safe zone” for placing the tunnel has been defined as 9 mm lateral to the midline of the tibial plateau and 3 mm lateral to the center of the tibial tubercle and adjacent to the anterior margin of the tibial plateau [1][2]. However, due to its close proximity to the tibial attachment of the anterior medial (AM) meniscus, it is unknown whether the described “safe zone” for IM nail insertion compromises the structural properties of the AM meniscal root, namely the overall attachment area and ultimate failure strength. Therefore, the purpose of this study was to quantify the area of the AM meniscal root footprint damaged by reaming for an IM tibial nail and determine its subsequent effects on the ultimate failure strength of this root in comparison to paired, native knees. It was hypothesized that reaming of the tibia using currently accepted guidelines for nail insertion would significantly weaken the AM root via a decrease in attachment area and strength in both male and female specimens.

Methods: Twelve matched pairs (6 male; 6 female; average age, 50.2 years) of human cadaveric knees were randomly assigned to native and reamed groups. In the reamed group, knees were reamed (Figure 1) within the “safe zone” according to current guidelines for IM tibial nail insertion.
Figure 1. Photograph demonstrating the currently recommended starting point for tibial IM reaming. Prior to reaming, the location was established and standardized using a digital caliper and bony landmarks, and a 3.2 mm guide pin was drilled. A 12.5 mm reamer was placed over the guide pin and the tunnel was reamed (left knee, M = medial, L = lateral).
The before and after reaming attachment areas of the AM meniscal root were quantified using a coordinate measuring device and Heron’s formula. In addition, the medial-lateral width and anterior-posterior length of the tibial plateau were measured for each specimen. A dynamic tensile testing machine was used to precondition each root from 10 to 50 N at a rate of 0.1 Hz for 10 cycles and subsequently pull to failure at a rate of 0.5 mm/s (Figure 2).

The ultimate failure strengths were determined, and a nonparametric Wilcoxon Signed-Rank test was used separately for the male and female groups to determine whether the reamed specimen produced lower ultimate failure load than its paired intact specimen. **Results:** Intra-articular reaming within the “safe zone” for IM tibial nail insertion did not affect the AM root attachment areas or significantly decrease ultimate failure strengths in male specimens, as only two of the six knees were damaged by reaming (Table 1).

In contrast, all six of the AM roots in the female knees were damaged by reaming, and on average, reaming decreased the female AM root attachment area by 19% and significantly decreased ultimate
failure strength by 37% (p = 0.028). There was a high negative correlation ($R^2 = 0.77$) between the reamed tunnel-AM root overlap area and medial-lateral width in females, but not males.

**Discussion:** The most important finding of this study was that female knees were susceptible to iatrogenic damage to the AM meniscal root during reaming based on the current recommended guidelines for IM nail insertion. In contrast, male knees were not significantly affected by reaming. This study was the first to quantitatively assess the anatomical and biomechanical impact of reamed tibial nailing on the structural properties of the AM meniscal root, and perhaps more importantly, compare these results between human male and female knees. This study concluded that standard reaming for IM tibial nailing induced significant damage to the AM meniscal root in smaller, female specimens, whereas larger, male specimens were not affected.

**Significance:** These findings may suggest that improvements in current guidelines and surgical techniques are warranted to prevent iatrogenic injury to the AM root during reaming for tibial shaft fractures in females and smaller patients.

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