

High Resolution Qualitative and Quantitative MR Imaging of the First Metatarsophalangeal Joint at 11.7T and 3.0T with Anatomic and Histologic Correlation

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Introduction: The first metatarsophalangeal (MTP) joint is a critical element in controlling the structural integrity of the foot. As the weight of the body transfers forward, the calcaneus and the heads of the metatarsals are pressed to the ground, with the arch functioning as a truss.

The importance of the first ray to the mechanics of the foot is, in part, because of the MTP joint's location, which intersects the transverse and medial longitudinal arches of the foot. A curved beam and a truss are frequently used when modeling the medial arch, designed to withstand bending under an applied force.

Pathology of the 1st MTP joint encompasses a variety of disorders from acquired orthopedic deformities and traumatic injuries to overuse problems and systemic disorders. These clinical problems typically involve the 1st MTP joint and are encountered daily by the foot and ankle surgeon.

The plantar plate has been identified as a major joint stabilizer and its definition and relationship within the capsuloligamentous complex has been incompletely described, with no literature addressing quantitative MR evaluation.

Purpose: The purpose of the study is 1) to provide high and ultra-high resolution morphologic evaluation of 1st MTP structures focusing on anatomic relationships and structural integrity, and 2) to provide the first quantitative MR evaluation of cartilage, ligaments, and tendons crucial to joint stability.

Methods: Five fresh-frozen cadaveric forefeet were utilized for this study. Imaging of the 1st MTP joints was performed on a 3.0T clinical MR system (General Electric Healthcare Medical Systems, Milwaukee, WI, United States) with a 2D intermediate-weighted sequence (TR 2000ms TE 35ms) and a 3D FSPGR sequence (TR 50ms TE 5.2ms). Imaging was also performed on an 11.7T MR system (**Fig. 1**) with a spin echo sequence (TR 5000ms TE 10ms). Quantitative ultra short time echo (UTE) images of important structures divided in 3 categories (tendons, ligaments and articular calcified layer) were acquired on the axial, coronal, and sagittal planes to determine the T2* intrinsic values. Each specimen was subsequently examined and dissected by an orthopedic surgeon and gross and histologic correlation were performed.

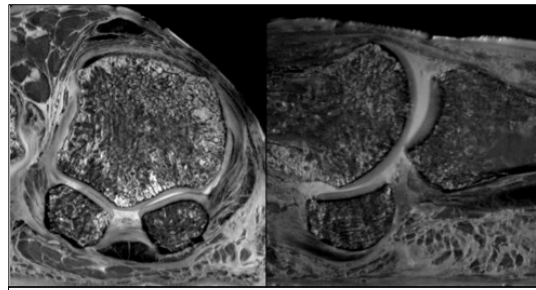


Fig.1: MR images at 11.7T showing ultra-high resolution imaging of capsuloligamentous complex, flexor and extensor hallucis tendons, and articular cartilage surface of the 1st MTP joint.

Results: The individual structures of the plantar plate complex and surrounding structures were exquisitely illustrated, with high and ultra-high morphologic images allowing structural characterization and anatomic relationships. The plantar plate is the greatly thickened portion of the plantar capsule that courses from a weaker attachment on the metatarsal head to a more firm attachment on the proximal phalanx. In the 1st MTP joints, the collateral ligaments, sesamoid bones, metatarsal-sesamoid ligaments, sesamoid-phalangeal ligaments, and intersesamoid ligament are dynamically stabilized by the short flexor complex (the two heads of flexor hallucis brevis tendon), the adductor hallucis tendons (transverse and longitudinal heads), and the abductor hallucis tendon, thus making a plantar plate complex which distinguishes the great toe from the lesser toes. T2* values of important structures, the calcified layer of articular cartilage, intersesamoid ligament, and flexor hallucis longus tendon were 2.4ms (± 0.2), 5.4ms (± 0.4), and 2.5ms (± 0.3), respectively (**Fig. 2**).

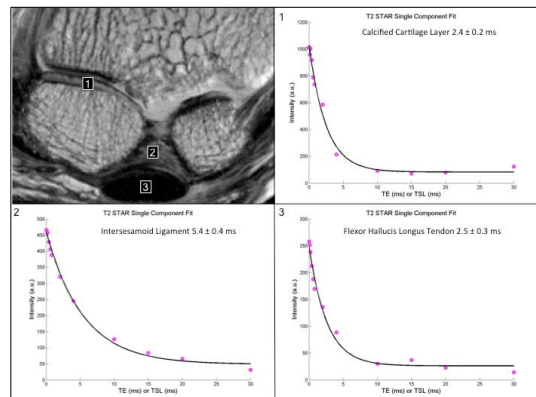


Fig.2: T2* values of three important structures: the calcified layer of articular cartilage (1), intersesamoid ligament (2), and flexor hallucis longus tendon (3).

Discussion: Although the importance of the 1st MTP joint and its variety of disorders has been widely described, there is discrepancy regarding the nomenclature and inconsistent anatomical descriptions in the literature, especially with regards to the plantar plate complex.

Through high resolution MR imaging at 3.0T and 11.7T, different structures of the 1st MTP joint have been evaluated. By correlating the MR images with histology and gross evaluation, we demonstrate that the 1st plantar plate is not a single structure, but rather a dynamic capsuloligamentous complex. Quantitative T1 and T2* intrinsic values of important structures of the 1st MTP joint may allow for earlier diagnosis of disease, better characterization of the stage of injury, and therapeutic monitoring.

References:

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