Evaluation of Meniscal Extrusion with Posterior Root Disruption and Repair using Ultrasound

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Introduction: Disruptions of meniscal fibers, including radial tears and root tears, have been shown to cause dysfunction of the meniscus as a load-bearing structure. Previous studies demonstrated that radial tears of the lateral meniscus produce increased pressure forces and decreased contact area between the femoral and tibial articulations. In addition, significant meniscal extrusion is associated with inefficient load-sharing and increased pressure forces across the knee joint. These additional stresses and associated decreased contact surface area can contribute to the advancement of knee osteoarthritis. The purpose of this study was to measure the relative position of the lateral meniscus within the knee under physiologic loads and as a function of the status of the posterior root. Meniscal position was measured using an inexpensive, portable ultrasound machine. Our hypotheses were that (1) a significant increase in the amount of lateral meniscal extrusion would be exhibited with 50% and 100% posterior root tears compared to intact menisci, (2) imaging under loaded conditions would yield significantly larger extrusion measurements compared to unloaded state, and (3) meniscal position and extrusion following posterior root repair would correlate with the intact state.

Methods: Ten unmatched, fresh-frozen cadaver legs were included (mean age, 68.5 years; range, 24-94 years). Specimens were prepared by transecting the femur 30-35 centimeters (cm) above the joint line and the tibia 22-27 cm below the joint line while preserving the collateral and cruciate ligaments. Skeletonized portions of the proximal femur and distal tibia were fixated in Bondo cement (3M, Saint Paul, MN; creating a square potting fixture. A custom mechanical load frame was used to apply a static, physiological (70 kg) axial load through the knees. A portable Sonosite Micromaxx ultrasound (FUJIFILM SonoSite, Bothell, WA) was utilized for image capturing of the lateral meniscus in association with (1) an intact posterior root attachment, (2) a 50% cut posterior root, (3) a 100% cut posterior root, and (4) repaired posterior root attachment. Images were obtained on each knee while in an unloaded condition, and again while loaded with 70 kg for each of the above injury levels, and again following repair. Ultrasound images were uploaded to a computer-based image viewing system for extrusion measurements. Lateral meniscal extrusion was defined as the distance from the outer rim edge of the meniscus to the lateral-most edge of the tibial plateau. (See Figure 1)

Results: Significant differences in extrusion were noted between the intact and 50% cut groups (p=0.028), between the intact and 100% cut groups (p<0.001), and between the 50% cut and 100% cut data groups (p=0.016) all in the loaded position. No significant difference was found in extrusion between intact state and repaired posterior root (p=0.174) in the axially-loaded position. Data was analyzed using a two-factor ANOVA with replication to detect significance in the amount of extrusion between loading groups and cut states. ANOVA revealed both load (p=0.003) and injury level (p=0.005) to have significant effects on the mean extrusion of the lateral meniscus. (See Figure 2)
Discussion: Using an in vitro cadaver model, we demonstrated that both axial-loading of the knee and sectioning of the lateral meniscus posterior root will produce significantly increased lateral extrusion of the meniscus. Following arthroscopic posterior root repairs, the measured lateral meniscal extrusion in the supine and axial-loaded positions following successful root repair closely mimicked that of the intact state. This represents an important finding with regards to restoration of lateral meniscal function and contact mechanics through prevention of extrusion. In addition, our study demonstrates the ability to analyze the lateral meniscal position in an axially loaded knee using a hand-held ultrasound machine. Portable ultrasonography can be a reproducible and reliable tool for dynamic meniscal examination in the clinical setting. In contrast to a static examination, such as MRI, ultrasound devices can detail dynamic information of meniscal position with weight-bearing and with flexion, and additionally can provide comparative data to the patient’s contralateral knee.

Significance: Significant extrusion is associated with axial loads in the setting of disrupted meniscal function, such as posterior root tears. This diagnosis should be considered a critical risk factor for accelerated progression of osteoarthritis. Surgical intervention to stabilize the meniscus within the incongruent femorotibial articulations can help to restore meniscal function and position more closely with the native state. In addition, dynamic weight-bearing ultrasound can be used to diagnose meniscal extrusion without a discrete tear or for post-operative functional evaluation of meniscal repairs. Further clinical studies are needed to discern indications and technique to best address this often under-appreciated clinical presentation.
Figure 1: Example ultrasound image of meniscal extrusion measurement.
Figure 2. Meniscal Extrusion for stages of injury and repair under both loaded and unloaded conditions. Error Bars represent 95% confidence intervals.