Sectioning of the Anterior Intermeniscal Ligament Changes Knee Loading Mechanics

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Purpose: The purpose of this cadaver research project was to describe the biomechanical consequences of anterior intermeniscal ligament (AIML) resection on menisci function under load conditions in full extension and 60° of flexion. **Methods:** Ten unpaired fresh frozen cadaveric knees were dissected leaving the knee joint intact with its capsular and ligamentous attachments. The femur and tibia were sectioned 15 cm from the joint line and mounted onto the loading platform. A linear motion *x-y* table allows the tibial part of the joint to freely translate in the anterior-posterior direction. K-scan sensors were used to define contact area, contact pressure, and position of pressure center of application (PCOA). Two series of analysis were planned: before and after AIML resection, mechanical testing was performed with specimens in full extension (1,400 N load) and in 60° of flexion (700 N load) to approximate heel strike and foot impulsion during the gait. **Results:** Sectioning of the AIML produced mechanical variations below the 2 menisci when specimens were at full extension and loaded to 1,400 N: increasing the mean contact pressure (delta 0.4 ± 0.2 MPa, +15% variation $P =$ .008) and maximum contact pressure (delta 1.50 ± 0.8 MPa, 15% variation $P <$ .0001) and decreasing of tibiofemoral contact area (delta 71 ± 51 mm^2, -15% variation $P <$ .0001) and PCOA (delta 2.1 ± 0.8 mm). At 60° flexion, significant differences regarding lateral meniscus mechanical parameters were observed before and after AIML resection: mean contact pressure increasing (delta 0.06 ± 0.1 MPa, +21% variation $P =$ .001), maximal contact-pressure increasing (delta 0.17 ± 0.9 MPa, +28% variation $P =$ .001), mean contact area decreasing (delta 1.84 ± 8 mm^2, 4% variation $P =$ .3), and PCOA displacement to the joint center (mean displacement 0.6 ± 0.5 mm). **Conclusions:** The section of the intermeniscal ligament leads to substantial changes in knee biomechanics, increasing femorotibial contact pressures, decreasing contact areas, and finally moving force center of application, which becomes more central inside the joint. **Clinical Relevance:** AIML resection performed ex vivo in this study, might potentially be deleterious in vivo. Clinical studies focusing on preserving or even repairing the AIML are needed to evaluate those ex vivo elements.

The shock-absorbing function of the menisci arises from their ability to convert an axial load into circumferential hoop stresses. This function is closely related to a ligament-capsule-menisci complex as known as the "meniscal belt."[1] The loss of the meniscal belt leads to significantly increased tibiofemoral contact stress due to a greater amount of "extrusive displacement" of the menisci.[2,3] At the most anterior part of this belt, the anterior intermeniscal ligament (AIML) of the knee is tightened between the anterior parts of the menisci. The AIML is a variable structure[4] described as a small, thick structure, intricated within the retropatellar fat pad and connected to anterior cruciate ligament fibers.[5,6] Anatomic and magnetic resonance studies do not show agreement.[4,7,8] In contrast to the classic "horn insertion" of the AIML, Nelson and Laprade[8] described 3 types of insertion: type I AIML has attachments to the anterior horn of the medial meniscus and anterior margin of the lateral meniscus; type II AIML has medial attachment to the anterior margin of the medial meniscus and lateral attachment to the joint capsule anterior to the lateral meniscus; and type III AIML has medial and lateral capsular anterior attachments only,

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with no direct attachments to the anterior horn of the medial meniscus or to the lateral meniscus (Fig 1).

In their description Nelson and Laprade[8] found an AIML in 94% of the cases (47/50), while Aydingöz et al.[4] found it in only 53% of cases (121/229) in their magnetic resonance imaging (MRI) evaluation.

Current knee surgery, including arthroscopic or open procedures, places no emphasis on the identification and preservation of this belt at its anterior part, as represented by the AIML, which is often injured or neglected. The aim of this cadaver research project was to describe the biomechanical consequences of AIML resection on menisci function under load conditions in full extension and 60° of flexion.

We hypothesize that AIML resection will lead to decreased tibiofemoral contact areas and increased pressures in full extension and 60° of flexion.

Methods

Ten unpaired fresh frozen cadaveric knees (6 right/4 left knees) were chosen out of the knees available at the Centre de Thanatopraxie de la Faculté de Médecine de Marseille. Specimens were procured with funding support from the Société Francophone d'Arthroscopie. Specimens selection was done after macroscopic and radiographic inspection to rule out bone and joint anomalies; specimens with substantial knee arthritis, bone deformities, or evidence (scar, remaining hardware or prosthetic implants, previous bone cuts or drilling) of previous surgery were excluded. Institutional review board approval was not required because of the use of deidentified cadaveric specimens. The average age of the cadaveric specimens was 48 years (42-76 years). Each specimen was maintained in a freezer at 0°C before use and then thawed to room temperature for testing. Knees were dissected, leaving the knee joint intact with its capsular and ligamentous attachments. The femur and tibia were sectioned 15 cm from the joint line and potted onto custom jigs made of polymethylmetacrylate cement. Specimens were mounted onto an Instron 5566-A device (Instron, Norwood, MA). A linear motion *x-y* table allows the tibial part of the joint to freely translate in the anterior-posterior direction. This setup allowed 1° of freedom in flexion-extension during axial compression, thereby minimizing shear stresses during the loading process (Fig 2).

To evaluate tibiofemoral contact stress, the K-scan 4400 piezoresistive sensor system (Tekscan, South Boston, MA), with a standard pressure range of 62 MPa and sensor density of 62 different sensors per cm^2, was used. Those sensors have a minimal resolution of 0.01 MPa (10 KPa) with a margin of error depending on applied force (2%-7%).[9,10] Anterior and posterior horizontal 3-cm capsulotomies were made (splitting horizontally the anterior and superficial part of the medial collateral ligament and doing a submeniscal dissection on the lateral side), and sensors were inserted avoiding the anterior and posterior horns of the menisci and the insertional ligaments below the 2 menisci following a previously described method.[2] Calibration was performed following information provided by the manufacturer.[2,11,12] A new sensor was used for each knee for 2 series of mechanical testing. Sensors were first conditioned by subjecting it to 3 cycles of axial loading from 0 to 1,800 N (130% of the compression load to be applied).

Two series of analysis were planned: specimens in full extension (Fig 3A) and 60° of flexion (Fig 3B) to approximate heel strike and foot impulsion during the gait.[13] A standard compression load of 1,400 N at a rate of 10 mm/min was applied to the knee in extension and held for 10 seconds; then, after positioning the knee at 60° flexion, a standard compression load of 700 N at a rate of 10 mm/min was applied. Each specimen was retested after 15-minute intervals to allow the knee to return to its unstressed state. The AIML was then sectioned with a no. 11 surgical blade, starting 1 cm above joint line, cutting down through the fat pad until tibial bone contact, and the 2 series of test were repeated. The 1,400 N and 700 N load were selected to approximate 1 and 2 time(s) the body weight for an average 70 kg individual.[14] Contact pressure, contact area, and a contact map were recorded in real time with 2 different analyses using Tekscan I-scan Pressure Measurement System software (Tekscan): (1) menisci evaluated together or (2) medial/lateral menisci

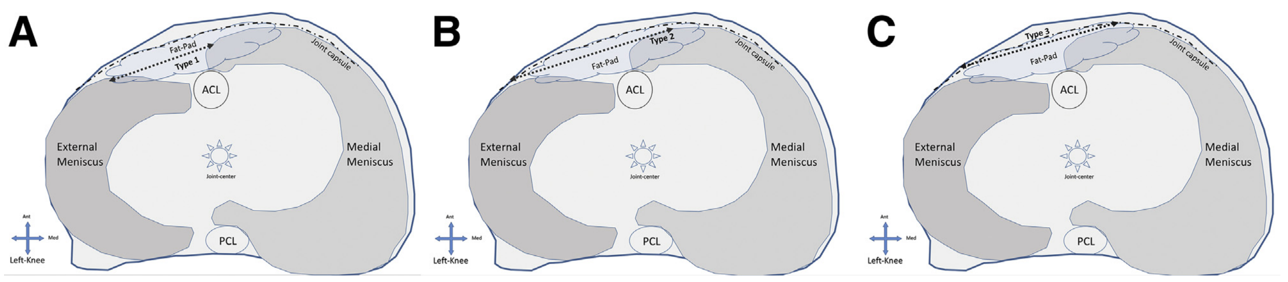

Fig 1. Scheme illustrating 3 Laprade and Nelson anterior intermeniscal ligament insertion types (A, type 1; B, type 2; C, type 3) on a left knee tibial plateau superior view.