Compressive Loads in Longitudinal Lateral Meniscus Tears: A Biomechanical Study in Porcine Knees

David P. Richards, M.D., F.R.C.S.C., F. Alan Barber, M.D., and Morley A. Herbert, Ph.D.

Purpose: To determine the displacement forces across a lateral meniscal tear during motion. **Type of Study:** Experimental laboratory biomechanical study. **Methods:** A middle third longitudinal lateral meniscal cut was created arthroscopically at the "red-white" junction in 5 intact porcine knees. With a pressure transducer in the tear, the knees were repeatedly cycled through a full range of motion. Pressure data were gathered with the knees held at neutral, internal rotation (IRot), and external rotation (ERot) and matched to the specific flexion angle measured by electronic goniometer. Averaged pressure measurements were calculated at each 5° interval. **Results:** The highest pressures were seen at full extension (neutral, 589 mm Hg; IRot, 1,110 mm Hg; ERot, 337 mm Hg) and declined to a low at 90° of flexion (neutral, 133 mm Hg; IRot, 314 mm Hg; ERot, 187 mm Hg). Then the pressures increased steadily after 100° as the knees were further flexed. The highest pressure was always seen with IRot. IRot during flexion resulted in higher lateral meniscus compressive loads than ERot. **Conclusions:** This model demonstrated that a middle third longitudinal lateral meniscal cut is compressed throughout the full range of knee motion. At no time were negative intrameniscal tear pressures registered that would suggest meniscal cut separation. **Clinical Relevance:** These data suggest that meniscal compressive loads, not distractive loads, occur throughout knee flexion and extension. The absence of distractive loads across a meniscal cut suggests that the ability of a repair to align the meniscal fragment may be more important than a high load to failure strength. **Key Words:** Meniscus tear—Meniscus repair—Repair device—Motion—Rehabilitation.

Meniscus repair rather than removal is a desirable goal whenever possible. Whether the repair is performed inside-out, outside-in, or all-inside, the goal of the repair is to hold the meniscus in a stable position until healing is sufficiently advanced. More needs to be known about the biomechanics of a meniscal repair to be able to assess the effectiveness of the various repair techniques. One of these issues is the stability of the repair during motion.

The biomechanical stability of a meniscal repair is important for 2 reasons. First, this provides the necessary fixation while the torn meniscus heals. Secondly, the overall strength of the repair may dictate the appropriateness of specific rehabilitation protocols. Although several meniscal repair devices and techniques have been reported,[1-17] there are no studies that describe the loads within a meniscal tear. Consequently, the necessary fixation force required to hold a torn meniscus while it heals is unknown. Our hypothesis is that knee motion displaces a longitudinal lateral meniscus tear. The purpose of this study was to determine the displacement forces across a lateral meniscal tear during knee motion.

From the Institute for Bone and Joint Disorders (D.P.R.), Phoenix, Arizona; Plano Orthopedic and Sports Medicine Center (F.A.B.), Plano, Texas; and Advanced Surgical Institutes, Medical City Dallas Hospital (M.A.H.), Dallas, Texas, U.S.A.

Address correspondence and reprint requests to F. Alan Barber, M.D., Plano Orthopedic and Sports Medicine Center, 5228 W. Plano Pkwy, Plano, TX 75093, U.S.A.

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METHODS

Five freshly harvested, never frozen, porcine legs were obtained for this experiment. These legs were cleaned of skin and subcutaneous tissue, allowing localization of the stifle joint, which is the tibiofemoral/patellofemoral joint in the human. The legs were

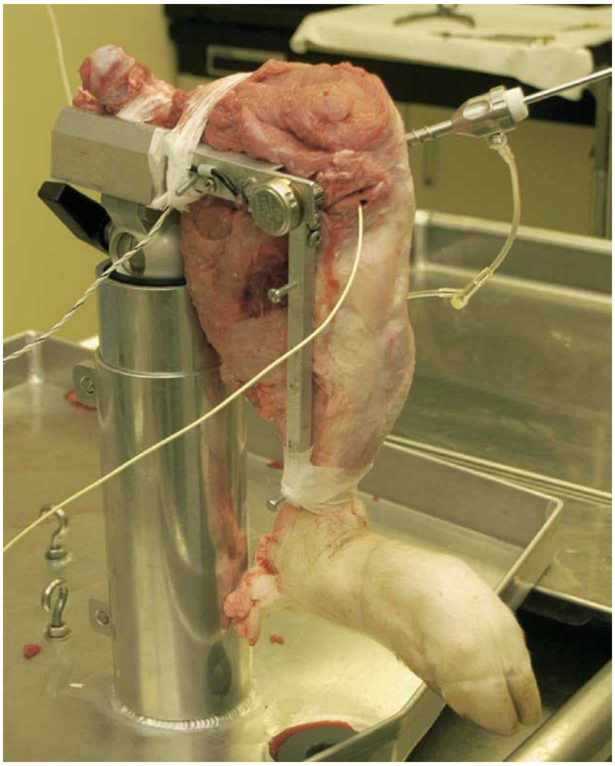

FIGURE 1. The pig legs were clamped in a stand with an electronic goniometer centered at the lateral joint line and secured to the femur and fibula. The goniometer was wired into the computer workstation, allowing kinematic analysis of the porcine knees. The arthroscopic visualization was done through the anterior medial portal and a pressure transducer was placed into the meniscal tear through the anterior lateral portal.

obtained from a local abattoir and kept refrigerated until testing. The pigs (*Sus scrofa*) weighed between 200 and 300 kg and were 3 to 4 years old at the time of slaughter. After ensuring that these limbs were thoroughly clean and that the knee joint was easily accessible, the experiment was initiated.

The pig legs were positioned in a stand by clamping the femur securely in a vice that allowed the leg to hang suspended (Fig 1). Once the femur was secure, an electronic goniometer was attached to the leg. The goniometer was centered at the lateral joint line and the device's arms were secured to the femur and fibula. The goniometer was wired into the computer workstation allowing kinematic analysis of the porcine knees. The knee was repeatedly cycled to ensure that the angular data was accurate and that the goniometer maintained its original position. Although the shape of the porcine meniscus and condyles are very similar to that of the human, extension is limited to 30° of flexion.

Next, an arthroscopic examination of the knee was performed. A central portal was made through the patellar tendon using a No. 11 blade scalpel and a 2.7-mm 30° arthroscope (Linvatec, Largo, FL) with its cannula and obturator were inserted into the joint. A video camera and light source were attached and a diagnostic arthroscopy performed. With arthroscopic control and probing with an 18-gauge spinal needle, an anterolateral portal was created. Both lateral and medial menisci as well as medial and lateral compartment chondral surfaces were examined to be certain that they were free of any pathologic changes. After the absence of pathology was confirmed, a No. 64 Beaver blade (W. Mueller, Allegiance Healthcare, McGaw Park, IL) was inserted through the anterolateral portal and a middle third longitudinal lateral meniscus cut created. All cuts were 2 cm in length and located 2 to 3 mm from the periphery of the meniscus (to attempt to approximate the "red-white" junction) in the middle third of the lateral meniscus. The probe was inserted into the lateral compartment and both superior and inferior meniscal surfaces were probed to ensure that a full-thickness cut had been created. With a full-thickness cut in the lateral meniscus confirmed, a pressure transducer (Millar Mikro-tip Pressure Transducer (5F); Millar Instruments, Houston, TX) was press-fit into the meniscal tear and checked arthroscopically to ensure that it did not move while the knee was cycled. The pressure transducer was positioned so that the data collection window was oriented toward the meniscal surface and away from the articular surface (Fig 2). Both its location in the meniscal tear and its orientation isolated the intrameniscal pressure from the direct pressure of the condyles. The data were relayed to the computer workstation for analysis.

The knee was manually placed through a full range of motion starting at full extension and progressing to full flexion and then back to full extension. Several cycles of the knee were performed for each test to obtain sufficient data points and consistency of the recordings. During these cycles, firm compressive pressure was maintained across the tibial-femoral joint. After each test, the arthroscope was reinserted into the knee joint to verify that the pressure transducer had not shifted. A total of 3 different positions were evaluated for each knee. For the first position, the knee was cycled in neutral rotation from full extension to full flexion; this was done 3 times. The second position cycled the knee from full extension into full flexion with the knee in maximal internal rotation (IRot). The third position cycled the knee