

Effect of Knee Flexion Angle on the Direction and Magnitude of Tensile Force in Complete Lateral Meniscus Radial Tears: A Porcine Biomechanical Study

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Disclosures: The authors have no relevant financial or non-financial interests to disclose

INTRODUCTION: The effect of the knee flexion angle on the direction and magnitude of tensile force on the meniscus during flexion and extension under a load is unknown. This study aimed to clarify this effect on repair sutures in a lateral meniscus (LM) radial tear of the midbody under knee-joint conditions during flexion and extension. We hypothesized that the direction and magnitude of the tensile force on the repair suture in a complete LM radial tear of the midbody would differ from the flexion under loading.

METHODS: The study protocol did not require approval from the Institutional Review Board of our institute, because all porcine knee specimens were obtained from a butcher. This study was performed using ten porcine knees, a robotic system with six degrees of freedom, and a load cell. Meniscal repairs were performed using horizontal sutures, with a single stitch between the central and peripheral regions at (1) the inner third position and (2) the outer third position, each meniscus sequentially. The suture of the posterior segment was drawn tangentially anteriorly, whereas the suture of the anterior segment was drawn tangentially posteriorly. The suture of the posterior segment was connected to an anterior load cell to measure the tensile force applied to the suture in the posterior direction. Subsequently, the suture of the anterior segment was connected to a posterior load cell to measure the tensile force applied in the anterior direction (Figure 1). A valgus load of 5 Nm was applied for three cycles at 30°, 60°, and 90° flexion. Statistical analysis was performed using two-factor repeated-measures analysis of variance to compare the flexion angles and stitching technique. A paired t-test was used for post-hoc analysis with Bonferroni correction. Statistical significance was set at $p < 0.05$.

RESULTS: All results are shown in Figure 2. The tensile forces on the inner and outer sides of the complete LM radial tears in the anterior and posterior directions differed significantly from the knee flexion angles. At 30° flexion, the tensile forces on the inner and outer sides in the anterior direction were significantly greater than those in the posterior direction ($p < 0.01$). At 60° and 90° flexion, the forces in the posterior direction were significantly greater than those in the anterior direction ($p = 0.02, < 0.01$). The tensile forces on the repair sutures (in both the anterior and posterior directions) showed no significant differences between the inner and outer meniscal sides at 30°, 60°, or 90° flexion.

DISCUSSION: The most important finding of this study was that, under 5 Nm valgus loading, the tensile force on the repair sutures in complete LM radial tears occurred anteriorly in the anterior segment at 30° flexion and posteriorly in the posterior segment at 90° flexion. Furthermore, the tensile force on the repair sutures in the anterior and posterior directions was not significantly different between the inner and outer meniscal sides at 30°, 60°, or 90° flexion.

The results of this study are consistent with the medial pivot and rollback motion relationship because the compressive loads reflect the converted tensile force considering knee meniscus function. Furthermore, these results are similar to those of a previous study that found load distribution and transmission through the LM in a complete radial tear of the midbody. It was assumed that the hoop structure converted the compressive forces equally into circumferential tensile forces on the inner and outer sides. Because the inner and outer sides of the meniscus are subjected to the same magnitude of tensile forces, it is desirable to suture both sides during meniscal repair.

This study had some limitations. First, freshly frozen porcine knees were used in this study. Second, we did not evaluate the peripheral meniscal gap under valgus loading. Third, as this study did not evaluate the failure load after meniscus repair for LM radial tears, it is not known to what extent a load can be considered to exert a safe level of tensile force. Fifth, this study is a time zero model, the result did not account for any biological healing or muscle activity.

CONCLUSION: Tensile force is exerted on the repair sutures in complete LM radial tears of the midbody, anteriorly in the anterior segment at 30° flexion and posteriorly in the posterior segment at 90° flexion.

SIGNIFICANCE/CLINICAL RELEVANCE: Rehabilitation protocols should account for variations in the direction and magnitude of the tensile force that differ from flexion angle under loading.

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Figure 1 Schematic diagram of the tensile force measurement method. LCL, lateral collateral ligament

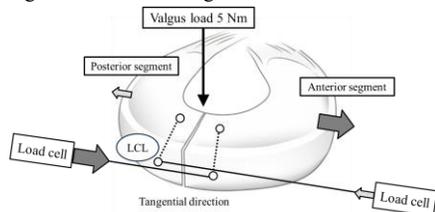


Figure 2 Influence of knee flexion angle on the tensile force exerted on repair sutures in anterior (a) and posterior (b) directions under a 5 Nm valgus load.

