Alterations in Knee Kinematics after Partial Medial Meniscectomy are Activity Dependant

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Introduction: Meniscal tears are one of the most common knee injuries with an incidence rate of 60-70/100,000 per person-year¹. While arthroscopic partial meniscectomy, the leading treatment, reduces pain, patients still have a four-times increased risk for knee osteoarthritis (OA) sixteen years post-operation². While the loss of meniscal tissue can cause increased cartilage stress, there are also reports of kinematic changes (rotational offset and extension deficit) in the meniscectomized knee during gait³-⁵ that support a kinematic pathway to OA of the knee. Specifically, changing knee mechanics can transfer the location of tibiofemoral cartilage contact to regions of cartilage not conditioned to the altered loading⁶ and thus initiate a degenerative pathway that can be accelerated by increased stress. However the lack of information regarding the static alignment and mechanics of the knee during other activities of daily living that induce increased joint loading, such as stair ascending and descending⁷, limits the understanding of disease etiology as well as options for new treatments. Therefore, this cross-sectional study of medial meniscectomy patients six months post-operation aims to test the following hypotheses: H1) The offset towards external rotation for the meniscectomized limb compared to the contralateral limb during stance will increase with activity demand. H2) The deficit in knee extension at initial foot contact for the meniscectomized (versus contralateral) limb will increase with activity demand.

Methods: Thirteen subjects (two female) with partial medial meniscectomies participated in the study after providing IRB-approved informed consent. The subjects were all able to walk, ascend stairs, and descend stairs without pain, reported no symptoms of osteoarthritis, and had no injury to the major ligaments of the knee joint, cartilage, or lateral meniscus. The demographics of the subjects were: age 38 ± 10 years (mean ± SD), height 1.8 ± 0.1 m, and weight 80 ± 12 kg with an average time past meniscectomy of 6 ± 2 months (range: 3 to 11 months). The contralateral knee of each subject was used as a matched control. Three trials each of walking, stair ascending (21 cm step), and stair descending were collected for both limbs of all subjects. A static reference pose was also captured for comparison. An eight-camera opto-electronic system for 3-D motion analysis (Qualisys, SE) was used to collect lower limb movements. The six-degrees-of-freedom knee kinematic measurements were derived from a previously described point cluster technique⁸ using the software application BioMove (Stanford University, CA). Knee flexion at initial contact (when the foot first contacts the floor or stair) and the average rotation during the stance phase were analyzed. This was an observational study and mean kinematic values were compared using one-tailed Student’s t-test with α = 0.05.

Results: Comparing the meniscectomized and contralateral limbs for each activity, on average throughout stance, the meniscectomized limb was significantly more externally rotated than the contralateral limb during stair ascending (p = 0.02) and stair descending (p = 0.005, Figure 1a). Furthermore, this limb difference increased with activity demand; there was a greater rotational difference between the meniscectomized and contralateral limb during stair descending than during stair ascending (p = 0.05), walking (p = 0.01), and static reference (p = 0.02).

At initial contact, the meniscectomized knee was more flexed (less extended) during walking (p = 0.05), stair ascending (p < 0.001), and stair descending (p = 0.004) compared to the contralateral knee (Figure 1b). During the static reference pose, there was a trend toward a more flexed meniscectomized versus contralateral limb (p = 0.09). Again, the limb difference in initial contact flexion angle increased with activity demand; the difference was greater during stair ascending and descending than the static trial (p = 0.006, p = 0.03) and greater during stair ascending than walking (p = 0.01).

Discussion: The tibia rotation limb differences seen during dynamic activities post-operation are consistent with structural changes of the knee due to partial medial meniscectomy as 98% of medial meniscal tears include the posterior portion of the meniscus⁹; removing this portion of the meniscus diminishes its capability to restrain the medial femoral condyle from translating posteriorly on the medial tibia, resulting in greater external tibial rotation. Furthermore, the increase in rotational differences seen during higher load activities (traversing stairs) suggests that the femur slips farther into the void of meniscal tissue under greater loading.

During dynamic activities, the meniscectomized knee was consistently more flexed at initial contact, suggesting that these patients have developed a possible neuromuscular adaptation just prior to load acceptance. The greatest limb difference in flexion angle was seen during stair ascent, when the knee is at about 65 degrees flexion and limb muscles must contract concentrically to lift the body onto the stair. Conversely, this adaptation was present to a lesser extent during walking and stair
descending, when the knee is near full extension (a more stable knee position than during greater flexion) and the muscles are contracting eccentrically to lower the center of mass. While the cause of this adaptation is yet unknown, these factors suggest that it may be related to knee instability or strength deficits post-operation. Alterations in rotation and flexion angles can cause a shift in the location of tibiofemoral cartilage contact thus loading unconditioned regions and possibly initiating OA. These changes are consistent with other OA at-risk populations: greater external rotation is seen in the operated limb after anterior cruciate ligament reconstruction, and increased flexion angle at initial contact is shown in the anterior cruciate ligament reconstructed population and the aging population\textsuperscript{10,11}. The greater kinematic limb differences seen during more demanding activities with greater knee loading illustrate the importance of investigating activities of daily living in addition to gait. These findings provide additional support for a mechanical pathway between partial meniscectomy and the initiation of OA, and, importantly, provide an opportunity for intervention. Muscle strength and neuromuscular training aimed to restore rotation and flexion angle symmetry between knees could return cartilage loading patterns to pre-operative conditions, protecting the cartilage from degradation and osteoarthritic changes.

**Significance:** By comparing multiple activities, this study suggests that kinematic alterations after meniscectomy are likely due to altered joint structure and neuromuscular adaptation. The specific kinematic differences identified provide guidance for rehabilitation programs post-operation for prevention of cartilage damage.

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**References:**

Figure 1: Limb differences in average stance rotation angle (a) and initial contact flexion angle (b) for static and dynamic activities.

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