Lateral Meniscus Extrudes With and Without Root Tear: A robotic study using ultrasound

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Introduction

Meniscus extrusion by ultrasound is known to assess meniscus function by measuring meniscus displacement and deformation.[1] Posterior lateral meniscus root injury is found in combination with ACL injuries in 7-12% of patients.[2] Despite various treatment techniques, the reported healing rate of lateral meniscus injuries is low.[3] Measuring lateral meniscus extrusion may help surgeons guide treatment and assess the function and status of the repaired meniscus.

Objective

1) Establish ultrasound method to assess lateral meniscus extrusion
2) Compare lateral meniscus extrusion and knee kinematics between intact and injured knees (posterior root tear)

Hypothesis

External loads and increasing knee flexion will result in increased lateral meniscus extrusion.

Methods

Specimens:

- 8 fresh-frozen human knees (mean age 57.6 ± 4.7 years)
- 3 knee states - intact, injured (lateral posterior root tear), and lateral meniscus deficient

Test Protocol:

- Loads applied at full extension, 30, 45, 60, and 90 degrees of flexion with 6-DOF robot
  - Passive Path (no loads)
  - 5 N- m of valgus torque
  - 5 N-m of internal torque
  - 200 N of axial compressive

Measurements:

- 6-DOF Knee kinematics
- Lateral meniscus extrusion of 3 different observers (ST, RT, TD) using ultrasound

Ultrasound Measurements:

1) Find lateral epicondyle, Gerdy's tubercle, and fibular head
2) Probe on lateral side of knee in oblique longitudinal orientation
3) Straddle femoral condyle proximal to new bony landmark
4) Extrusion – distance between two parallel lines:
   A. Margin of the tibial cortex
   B. Outermost edge of meniscus

Methods

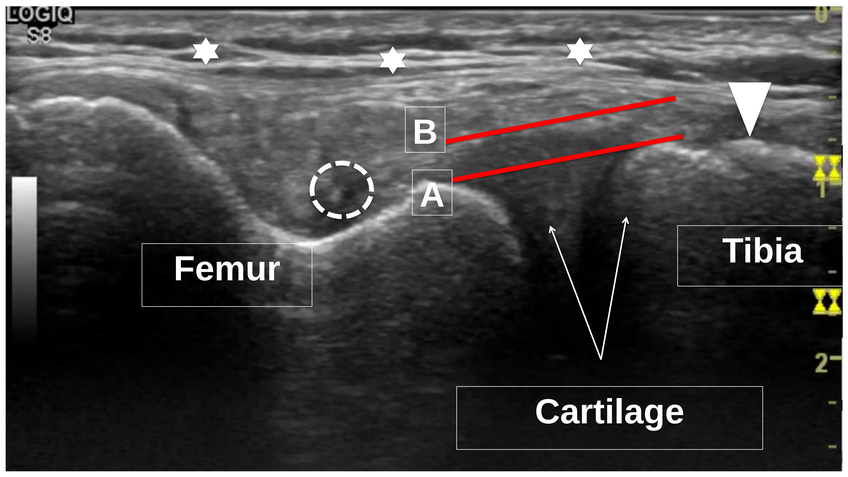

Figure 1: Ultrasound image of intact lateral meniscus
Dotted circle – insertion area of popliteal tendon
White arrow head – created bony landmark
Stars – iliotibial band
A – margin of tibial cortex
B – outermost edge of meniscus

Statistical Analysis:

- Inter-rater and intra-rater reliability coefficient from ANOVA table
- Kinematics, flexion, and loads analyzed with Wilcoxon signed rank test

Results

- Ultrasound measurement showed good inter-rater (0.65 - 0.71) and intra-rater repeatability (0.81)
- Meniscus extrusion
  - Increased in injured knees relative to intact knees under all external loads at all angles
  - Decreased with increasing flexion angles
- No difference in kinematics between intact and injured knees

Table 1: Lateral meniscus extrusion at 0°, 36°, 60°, and 90° of flexion in response to 5 Nm valgus tibial torque (mean ± SD)

Flexion angle	Lateral meniscus extrusion (mm)	
	Intact	Injured
0°	1.4 ± 0.6	2.4 ± 0.5
30°	1.3 ± 0.7	2.4 ± 0.7
60°	0.4 ± 0.8	1.7 ± 0.5
90°	-1.3 ± 1.3	0.6 ± 0.5

Table 2: Lateral meniscus extrusion at 0°, 36°, 60°, and 90° of flexion in response to 150 N of axial compression (mean ± SD)

Flexion angle	Lateral meniscus extrusion (mm)	
	Intact	Injured
0°	0.14 ± 0.06	0.21 ± 0.04
30°	0.12 ± 0.06	0.20 ± 0.07
60°	0.04 ± 0.08	0.14 ± 0.07
90°	-0.13 ± 0.11	0.06 ± 0.06

Results

Table 3: Inter-rater and intra-rater reliability with range

- Good inter-rater repeatability (0.65 - 0.71)
- Good intra-rater repeatability (0.81)

State	Inter-rater and Intra-rater Reliability (ICC [range])			
	ST vs. RT	TD vs. RT	TD vs. ST	Intra-rater (TD)
Overall	0.65 [0.30-0.97]	0.68 [0.29-0.91]	0.71 [0.34-0.94]	0.81 [0.43-0.99]
Intact	0.62 [0.30-0.94]	0.65 [0.36-0.90]	0.68 [0.34-0.92]	0.84 [0.67-0.99]
Injured	0.69 [0.40-0.97]	0.70 [0.29-0.91]	0.74 [0.59-0.94]	0.78 [0.43-0.97]

Discussion

- Injured lateral menisci extruded differently from healthy menisci when loaded
- Previous reports using unloaded MRI and no loads might be underestimating lateral meniscus extrusion
- Previous studies using internal tibial rotation might not be loading lateral meniscus enough
- Avoid deep flexion angles when measuring lateral meniscus extrusion
- Ultrasound measurements performed in standing patients can be helpful to clinically assess meniscus function and status pre- and postoperatively

Disclosures: No author has a conflict of interest concerning this research.

References

1) Crema MD,et al. Radiology 2012.
2) Schillhammer CK, et al. AJSM. 2012.
3) Feucht MJ, et al. Arthroscopy. 2015