Non-anatomic Femoral Tunnel Placement Increases the Risk of Subsequent Meniscal Surgery after ACLR in Patients Without Recurrent ACL Injury

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INTRODUCTION: Appropriately placing the anterior cruciate ligament (ACL) graft within the native insertion sites during primary ACL reconstruction (ACLR) is important to protect the meniscus from further injury since the ACL and menisci are biomechanically interdependent. A previous study found that an anterior femoral tunnel position increased the risk of subsequent meniscal surgery in patients undergoing ACLR. However, the study included patients who sustained a recurrent ACL reinjury and risk factors for subsequent meniscal surgery in patients without recurrent ACL injury is not well described. Therefore, this study aimed **t**o identify risk factors for subsequent meniscal surgery following ACLR in patients without recurrent ACL injury.

METHODS: Patients who underwent primary ACLR from 2014 to 2022 with minimum 1 year follow-up were retrospectively reviewed. Exclusion criteria included age <14 years, multi-ligament knee surgery, double-bundle or over-the-top techniques, and recurrent ACL injury with suspected residual anterior instability (softened endpoint on Lachman test) or confirmed by magnetic resonance imaging, or patients undergoing subsequent revision ACLR. Patient demographics and surgical data at the time of ACLR were collected. Postoperative strict lateral radiographs (<6 mm of condylar overlap) were used to measure femoral tunnel position in the anterior-posterior (A-P) and proximal-distal (P-D) direction, tibial tunnel position in the A-P direction, and posterior tibial slope (Figure 1). The difference in distance between the femoral tunnel and the anatomic ACL footprint in both dimensions was standardized to the A-P length of the lateral femoral condyle and reported as percentage. Univariable and multivariable analyses were performed to identify risk factors for subsequent meniscal surgery.

RESULTS: A total of 2,079 ACLRs were initially identified, 629 of which were included (mean age, 24.8 ± 10.0 years; female, 49.3%; mean follow-up, 2.3 ± 1.6 years). Subsequent meniscal surgery was performed in 65 patients (medial, 69.2%; lateral, 23.1%; bilateral, 7.7%). The mean age was significantly younger in the subsequent meniscal surgery group than the no subsequent meniscal surgery group (22.1 ± 8.0 years vs. 25.1 ± 10.2 years, $P = 0.044$). Moreover, the rate of medial meniscus repair at the time of ACLR was significantly greater in subsequent meniscal surgery group than no subsequent meniscal surgery group (42/65 [64.6%] vs. 145/564 [25.7%], $P < 0.001$; Table 1). The femoral tunnel position was significantly more anterior in the subsequent meniscal surgery group compared to the no subsequent meniscal surgery group ($p = 0.024$; Table 2). In addition, a significant difference was found between groups for femoral tunnel position in the P-D direction ($p = 0.010$). The frequency of femoral tunnel placement >10% outside of the literature-established anatomic position was significantly higher in those who underwent subsequent meniscal surgery compared to those who did not (38.3% vs 20.3%, $P = .006$). Multivariable analysis revealed that medial meniscal repair at the time of ACLR, younger age, and femoral tunnel difference from anatomic position were significantly associated with subsequent meniscal surgery ($p = 0.015$, $p < 0.001$, $p = 0.002$, respectively; Table 3). Posterior tibial slope and ACL graft type weren't significantly associated with subsequent meniscal surgery.

DISCUSSION AND CONCLUSION: Medial meniscal repair at the time of ACLR, younger age, and non-anatomic femoral tunnel placement were risk factors for subsequent meniscal surgery in patients without recurrent ACL injury. Femoral tunnel placement <10% outside of the native anatomic position during initial ACLR is important to reduce the risk of subsequent meniscal surgery.

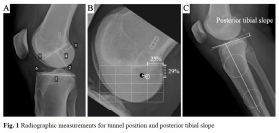

Fig. 1 Radiographic measurements for tunnel position and posterior tibial slope

A) Femoral tunnel position was described as a percentage of the anterior-posterior (A-P) (line 3/line 1) and proximal-distal (P-D) direction (line 4/line 2). Tibial tunnel position was measured as a percentage of the anterior-posterior direction (line 6/line 5). B) The distance from reported anatomic position (white circle; A-P direction; 25%, P-D direction; 29%) to the center of the femoral tunnel position (black circle) were calculated and standardized by dividing by the condylar width (line 1). Anatomic tunnel placement was determined by ≤10% difference from native insertion. C) Posterior tibial slope was measured as the angle between tibial plateau and the line tangent to the anatomic axis of the tibia using "the circle J-point method".

Table 1. Comparison of patient characteristics between groups

Variable	Subsequent meniscal surgery (n = 65)	No subsequent meniscal surgery (n= 564)	*P* value
Age, years	22.1 ± 8.0	25.1 ± 10.2	**0.044**
Sex [female]	34 (52.3%)	276 (48.9%)	0.607
Body mass index, kg/m^2	26.2 ± 4.8	26.8 ± 5.6	0.396
ACL Graft type [BS/QT/BPTB/Allo]	11/18/20/16	127/157/151/129	0.741
Medial meniscus repair at the time of ACLR	42 (64.6%)	145 (25.7%)	**< 0.001**
Lateral meniscus repair at the time of ACLR	16 (24.6%)	114 (20.2%)	0.407
Medial meniscectomy at the time of ACLR	3 (4.6%)	52 (9.2%)	0.213
Lateral meniscectomy at the time of ACLR	10 (15.4%)	64 (11.3%)	0.339

Data are reported as mean ± SD in the case of continuous variables or count (%) in the case of categorical variables. Statistical significance (p < 0.050) is indicated in bold. ACLR, anterior cruciate ligament reconstruction. HS, hamstring tendon, QT, quadriceps tendon, BPTB, bone-patellar tendon-bone, Allo, allograft.

Table 2. Comparison of tunnel position and tibial posterior slope between groups

Variable	Subsequent meniscal surgery	No subsequent meniscal surgery	*P* value
Femoral tunnel A-P	n = 47	n = 354	**0.024**
(<30%, anterior)	18 (38.3%)	82 (23.2%)	
Femoral tunnel P-D	n = 47	n = 354	**0.010**
(<28%, proximal)	9 (19.1%)	94 (26.6%)	
(28%-39%)	18* (38.3%)	181* (51.1%)	
(>39%, distal)	20* (42.6%)	79* (22.3%)	
Femoral tunnel difference from anatomic position	n = 47	n =354	**0.006**
(>10%, non-anatomic)	18 (38.3%)	72 (20.3%)	
Tibial tunnel A-P	n = 47	n = 354	0.174
(<35%, anterior)	7 (14.9%)	84 (23.7%)	
Tibial posterior slope	n = 44	n = 303	0.880
(>12°)	9 (20.5%)	65 (21.5%)	

*Data are reported as count (%), the statistical significance (p < 0.050) is shown in bold. * p < 0.050 (residual analysis). A-P, anterior-posterior, P-D, proximal-distal.*

Table 3. Multivariate logistic analysis of risk factors for subsequent meniscal surgery including femoral tunnel difference from anatomic position

Variable	B	OR	95% CI	*P* Value
Age, year	-0.052	0.949	0.910-0.990	**0.015**
Medial meniscus repair	1.467	4.334	2.256-8.324	**< 0.001**
Femoral tunnel difference from anatomic position	1.055	2.872	1.451-5.684	**0.002**

Statistical significance (p < 0.050) is indicated in bold. The analysis was performed with 401 cases, excluding the cases with any missing data for the variables.