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Anteromedial Portal Drilling Reduces Posterior Cruciate Ligament Impingement during Anterior Cruciate Ligament Reconstruction

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Methods: Eight cadaveric knees were evaluated arthroscopically. Femoral tunnels used for ACL reconstruction were then drilled using both an anteromedial portal technique as well as a trans-tibial technique. Qualitative and quantitative comparisons of each technique's ability to center a femoral tunnel in a non-PCL impinging position within the native ACL femoral footprint were then recorded.

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GJMR-H Classification: *NLMC Code: WS 270, WE 304*

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Results: Of eight tunnels drilled through an anteromedial portal, none showed signs of PCL impingement and all were centered in the native ACL footprint. Three tunnels (37.5%) drilled trans-tibially showed signs of potential PCL impingement starting at 90 degrees flexion, and all were displaced superior to the center of the native ACL footprint by an average of 3.25 mm.

Conclusion: Femoral tunnels drilled through an anteromedial portal technique were consistently placed in the center of the ACL femoral footprint, and no potential impingement by the PCL was noted. Femoral tunnels drilled trans-tibially had a tendency to displace superiorly and three showed signs of impinging against the lateral border of the PCL.

Keywords: ACL; PCL; impingement; anatomic reconstruction.

What is known about the subject: Classic approaches to ACL reconstruction have led to PCL impingement and eventual ACL graft laxity.

What this study adds to existing knowledge: Use of the newer anteromedial approach to portal drilling during ACL reconstruction leads to decreased PCL impingement when compared to the trans-tibial approach.

I. Introduction

Posterior cruciate ligament (PCL) impingement following anterior cruciate ligament (ACL) reconstruction can often lead to post-operative graft instability and loss of knee range of motion. Second look arthroscopy studies have demonstrated that this is due to graft laxity caused by a combination of repetitive stress and high graft tension as the ACL presses against the lateral border of the PCL during flexion. 22 Howell et al. reported in a cadaver study that lowering the ACL graft on the "clock-face" resulted in a lower incidence of ACL-PCL impingement.9 He also noted that this femoral tunnel position, which is closer to the center of the anatomic ACL footprint, led to a decrease in graft tension of nearly 50 N.18

Many strategies have been devised to center a femoral tunnel in the anatomic footprint of the ACL. Loh et al. demonstrated improved rotational stability with the femoral aspect of the ACL graft oriented in the 10 or 2 o'clock position rather than the 11 or 1 o'clock position.14 Although the trans-tibial drilling method has been largely successful since its advent, recent evidence has demonstrated that its use often results in overly vertical grafts.2, 12, 16, 17, 23 As a result, to achieve optimal femoral tunnel position, many have abandoned the trans-tibial technique in favor of drilling the femoral tunnel independently using an anteromedial portal technique.3, 6, 21

The purpose of this study was to determine whether drilling method, anteromedial portal versus trans-tibial, affected the incidence of ACL-PCL impingement. In addition, we sought to devise an intra-operative test to help avoid ACL-PCL impingement. We tested the hypothesis that a femoral tunnel located in the center of the native ACL footprint was most consistently attainable through an anteromedial portal drilling technique, and that this method subsequently had a lower incidence of ACL-PCL impingement.

II. Materials and Methods

a) Specimen Selection

Eight (four matched pairs) cadaveric knees were evaluated (N = 8). The knees were obtained from specimens with an average age of 66 years old (range 56 to 74 years old). Inspection at the time revealed that all specimens had intact ACL, PCL, articular surfaces and menisci. None had significant degenerative joint disease. All knees underwent an initial diagnostic arthroscopy and were ranged from 0-120 degrees of flexion. All knees were noted to have no impingement of the native PCL against the native ACL.

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b) Creation of Femoral Tunnels and Evaluation for ACL-PCL Impingement

A 30-degree arthroscope was used to evaluate all knees through a lateral viewing portal and a medial working portal. After debridement of the ACL, a thin layer of the femoral attachment was left. This allowed visualization of the broad native ACL footprint that was defined and evaluated through a full arc of motion. Using a Beeth pin, a mark was placed in the anatomic center of the native ACL footprint via a percutaneous technique (Figure 1). For a single-bundle reconstruction, we considered the center as a point placed slightly anterior to the anatomic AM bundle insertion site, roughly 6 mm anterior to the posterior cortex at the 2-o'clock position for a left knee or 10-o'clock position for a right knee.5 An anteromedial portal technique was then used to create the first femoral tunnel.6 Assuming an average 8 mm graft, an 8mm core reamer was used to drill a femoral tunnel to a depth of 5 mm while keeping the knee in 120 degrees of flexion. The core reamer allowed outlining of the area a tunnel would occupy while preserving bone stock (Figure 2). The resultant tunnel was then observed as the knee was flexed from 0-120 degrees. If the PCL obscured any part of the femoral tunnel, it was assumed that PCL impingement would occur at that point in the arc of flexion. The overlapping of the femoral tunnel by the PCL was referred to as the "Femoral Eclipse Sign" (Figure 3).

The conserved bone stock allowed drilling of a second femoral tunnel in the same knee. This second tunnel was created using a trans-tibial method.15 A standard 8mm tibial tunnel was first made using a tip aiming elbow guide set at 53 degrees. The tunnel originated at a point on the tibial cortex hugging the anterior border of the medical collateral ligament and exited through the tibial plateau 7mm in front of the PCL and two-thirds up the medial tibial spine. A 6mm over-the-top guide was then inserted through the tibial tunnel, across the joint and into position on the femur. The knee was flexed to 90 degrees, and the over the top guide was placed on the femur as close as possible to the center of the anatomic ACL footprint (Figure 1). A guide-wire was then drilled into the femur to 40 mm, and an 8mm core reamer was used to drill a femoral tunnel to a depth of 5mm. The knee was then ranged from 0-120 degrees, and the incidence of whether the PCL obscured the trans-tibially drilled femoral tunnel was recorded.

In addition to recording the incidence of ACL-PCL impingement, the ability of both drilling methods to achieve a femoral tunnel position centered in the anatomic ACL footprint was measured. This was done arthroscopically using the tip of an arthroscopic probe (3mm). Both the magnitude and direction of displacement from the center of the native ACL footprint were measured (Figure 1).

c) Statistical Analysis

Statistical analysis was performed on the raw data obtained from this study. With regards to the presence or absence of the Eclipse Sign, a sign of potential ACL-PCL impingement, a McNemar's test was used. For analyzing displacement of the femoral tunnels from the center of the native ACL footprints, a signed rank test was performed. All p-values were set to 0.05.

III. Results

Upon arthroscopic examination of the native femoral ACL insertion from the lateral viewing portal, all eight cadaver knees demonstrated no overlapping of the ACL footprint by the PCL as the knee was ranged from 0-120 degrees of flexion. Using the anteromedial portal technique, the femoral tunnel guide-wire was placed into the center of the native ACL footprint in all eight knees. When femoral tunnels were drilled anteromedially, there were no instances where the PCL obscured any portion of the tunnel as the knee was flexed from 0-120 degrees (Figure 4). Of the eight tunnels drilled trans-tibially, all had the femoral tunnel guide-wire within the broad ACL footprint; however, after the core reamer was used to drill a tunnel, three cases showed clear evidence of a femoral tunnel being obscured by the lateral border of the PCL during flexion of 90 to 120 degrees when viewed from the lateral arthroscopy portal ($p = 0.25$). We called this finding the "Femoral Eclipse Sign" (Figure 3). This implied that a graft placed in those three tunnels would experience impingement against the lateral border of the PCL during high flexion.

When measuring the direction and magnitude of displacement from the absolute center of the native ACL footprint, it was noted that all tunnels drilled using the anteromedial portal method had zero displacement. With regard to the trans-tibially drilled tunnels, the three tunnels that showed signs of potential PCL impingement (positive Eclipse Sign) were displaced superiorly (Figure 5). The amount of superior displacement was measured to be 2 mm, 5 mm, and 5 mm. Of the remaining five tunnels drilled trans-tibially that did not show potential PCL impingement (negative Eclipse Sign), all were displaced anteriorly, superiorly, or anterosuperiorly from the anatomic center of the ACL footprint (Table 1). Overall, the degree of displacement from the center of the native ACL footprint of trans-tibially drilled femoral tunnels averaged 3.25mm ($p = 0.0078$, range 1 to 5 mm).

IV. Discussion

This study compared the incidence of potential ACL-PCL impingement using the traditional trans-tibial femoral tunnel drilling method15 to a technique of independent drilling through the anteromedial arthros-

copy portal.20 In addition, the ability to place a femoral tunnel in the center of the native ACL footprint using these two drilling techniques was measured. Recent literature has demonstrated many benefits of placing an ACL graft in a more oblique and anatomic orientation centered in the native ACL footprint.1, 4, 8-11, 13 These advantages include avoiding graft impingement on the PCL and the resultant increased graft tension, loss of knee flexion, graft laxity and failure that may accompany it. It has become recognized that a vertically oriented graft can lead to ACL-PCL impingement, fatigue failure and rotatory instability.23-26 To prevent these potential complications, many have advocated drilling the femoral tunnel independently through an anteromedial portal.6, 20, 26 This technique has consistently led to an anatomically placed single bundle ACL without the risk of creating a short femoral tunnel with possible violation of the posterior femoral cortex.7, 19

In our study, native femoral ACL footprints and femoral tunnels drilled through an anteromedial portal did not show signs of potential PCL impingement. In addition, all eight tunnels drilled anteromedially were centered in the native ACL footprint. Three tunnels (37.5%) drilled trans-tibially showed obscuring of the tunnel by the PCL as the knee was brought into high flexion – a sign that a graft placed into the tunnel would likely press against the lateral border of the PCL. Overlapping of the femoral tunnel by the PCL was referred to as the "Femoral Eclipse Sign," and this intra-operative finding was seen as a useful tool to avoid ACL-PCL impingement. All tunnels that showed a positive Eclipse Sign were displaced superiorly by an average of 4 mm – evidence that the tunnels were too vertical. We concluded that because femoral tunnels drilled through an anteromedial portal were oriented more anatomically, they did not show signs of potential PCL impingement. The three tunnels that showed signs of PCL impingement were likely the result of the trajectory of the tibial tunnel compromising the orientation of the femoral tunnel. In addition, the remaining five (62.5%) tunnels drilled trans-tibially that did not show signs of impingement were displaced from the absolute center of the native ACL footprint (Table 1).

Limitations to this study include using a cadaver model and the fact that the sample size is small. In having to drill two tunnels in a human femur to compare the anteromedial portal versus trans-tibial technique, it was not feasible to perform this study in an in vivo model. Using a cadaver model was advantageous, providing a distinct visual illustration of the potential difference in the two methodologies. The small sample size may have lead to less precise findings, as the statistical significance of the Eclipse Sign was definitely impacted. Still, the correlation between the incidence of the Eclipse Sign and drilling technique definitely showed that it is a useful intra-operative tool to signal a vertical, PCL-impinging graft position. The current study has shown that the proposed anteromedial portal drilling technique has the potential to decrease ACL-PCL impingement during ACL reconstruction.

Another weakness is the fact that an ACL reconstruction was not carried out to validate the Femoral Eclipse Sign. Performing ACL reconstructions in our specimens would require drilling complete femoral tunnels. We elected to use core reamers to outline the positions of the tunnels, thus preserving bone stock and allowing full visualization of two tunnel positions relative to the center of the native ACL footprint within the same knee. We believe that validating the Eclipse Sign is a necessary step in solidifying the conclusion that anatomic tunnel placement, most consistently achieved by the anteromedial portal drilling method, leads to a lower incidence of ACL-PCL impingement. As a result, a future clinical trial evaluating the Eclipse Sign and its correlation with true ACL-PCL impingement during ACL-PCL reconstruction is being planned.

The results of this study lead us to believe that a femoral tunnel centered in the native ACL footprint will not experience ACL-PCL impingement. From our experience, this orientation was most consistently achieved by drilling the femoral tunnel through an anteromedial portal.3, 6 Although Howell and Kondo have suggested modifications to the trans-tibial method to achieve a more anatomic graft placement, in our study, we were not able to obtain consistently accurate placement of the femoral tunnel using that technique. Regardless of the drilling method chosen, we recommend routinely checking for ACL-PCL impingement prior to graft insertion by observing whether the PCL obscures the femoral tunnel during high flexion – an intra-operative marker called the Femoral Eclipse Sign.

V. Conclusion

ACL-PCL impingement following ACL reconstruction can lead to increased graft tension, inability to achieve full flexion and graft laxity due to repetitive stress. To avoid this phenomenon, the femoral tunnel should be placed anatomically in the center of the native ACL footprint. This is most consistently achieved by drilling the femoral tunnel through the anteromedial arthroscopy portal. Future clinical studies are necessary to validate the Femoral Eclipse Sign.

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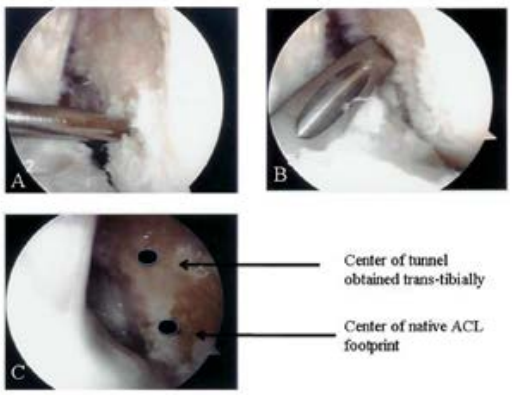

Fig. 1

a. Drill mark made in the center of the native ACL footprint.
b. Over-the-top guide inserted trans-tibially and an attempt made to place the tunnel in the center of the native ACL footprint.
c. Resulting superior displacement of the drill mark made trans-tibially relative to the center of the native ACL footprint.

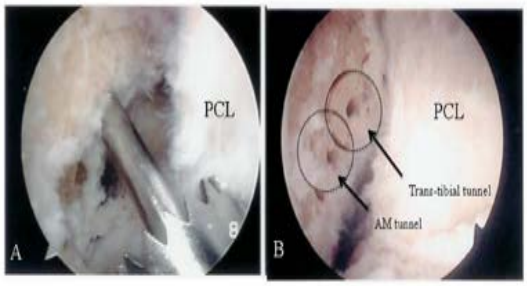

Fig. 2

a. Use of the core reamer allowed visualization of the femoral tunnel location while preserving bone stock – this allowed drilling of multiple tunnels in the same knee.
b. Illustration of the difference between the AM tunnel and the trans-tibial tunnel. Note the proximity of the trans-tibial tunnel to the PCL compared to the AM tunnel.

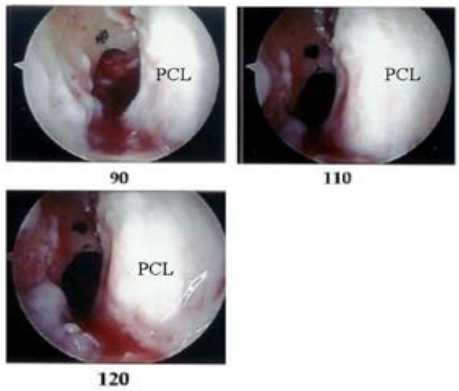

Fig. 3

The "Femoral Eclipse Sign." Tunnels drilled trans-tibially: as the knee is flexed from 90-120 degrees, the lateral border of the PCL obscures the medial aspect of the femoral tunnel. This is an intra-operative sign that any graft placed within this tunnel may potentially impinge against the PCL during knee flexion.

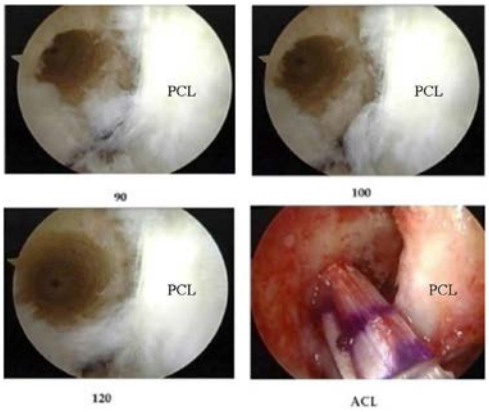

Fig. 4

Tunnels drilled through the anteromedial portal. No Eclipsing of the femoral tunnel is seen. The resulting graft does not impinge against the lateral border of the PCL at full flexion.

Fig. 5

The superior placement of the tunnel drilled trans-tibially compared to the tunnel drilled through the medial portal is illustrated here.

Table 1 : Three out of eight femoral tunnels drilled trans-tibially Eclipsed. All were positioned superior to the tunnel drilled though the medial portal

Data Set 1 : Presence of eclipse sign in femoral tunnels drilled through an anteromedial arthroscopy portal versus tunnels drilled trans-tibially

Knee	Native femoral ACL attachment	Tunnel drilled through anteromedial portal	Tunnel drilled trans-tibially
1	No eclipse	No eclipse	No eclipse
2	No eclipse	No eclipse	**Eclipse**
3	No eclipse	No eclipse	No eclipse
4	No eclipse	No eclipse	No eclipse
5	No eclipse	No eclipse	**Eclipse**
6	No eclipse	No eclipse	No eclipse
7	No eclipse	No eclipse	**Eclipse**
8	No eclipse	No eclipse	No eclipse

*0/8 femoral tunnels drilled through an anteromedial arthroscopic portal showed an Eclipse Sign – no sign of potential ACL-PCL impingement
**3/8 (37.5%) tunnels drilled trans-tibially showed an Eclipse Sign – thus there is a 37.5% chance of ACL-PCL impingement using the trans-tibial method

Data Set 2 : Amount and direction of displacement of femoral tunnels in relation to the native anatomic ACL footprint

Knee	Amount and direction of displacement: Anteromedial	Amount and direction of displacement: Trans-tibial
1	0mm	1mm anterior
2	0mm	5mm superior
3	0mm	4mm anterosuperior
4	0mm	1mm anterior
5	0mm	2mm superior
6	0mm	5mm anterosuperior
7	0mm	5mm superior
8	0mm	3mm anterosuperior

*All femoral tunnels drilled through an anteromedial portal were placed in the center of the native ACL footprint
*Femoral tunnels drilled trans-tibially were an average of 3.25mm displaced anterosuperior to the native ACL footprint