Comparison of Anteromedial and Transtibial ACL Reconstruction Using Expandable Fixation

OMER OZEL, MD; BULENT YUCEL, MD; OSMAN ORMAN, MD; EMRE DEMIRCAY, MD; SERHAT MUTLU, MD

abstract

The influence of anatomical or nonanatomical femoral tunnel position on tunnel widening and clinical outcomes in patients undergoing anterior cruciate ligament (ACL) reconstruction is not fully understood. This retrospective study examined the influence of tunnel width and placement on anterior knee stability and clinical outcomes after ACL reconstruction using the AperFix System (Cayenne Medical Inc, Scottsdale, Arizona), a direct expandable fixation technique with autologous hamstring grafts. The records of 80 patients (79 men and 1 woman) who underwent ACL reconstruction were evaluated. In 38 patients, anatomical femoral tunnel placement was performed via an accessory medial portal (anteromedial group); in the remaining 42 patients, the femoral tunnel was positioned nonanatomically using a transtibial technique (transtibial group). Mean follow-up was 40.7 months (range, 27-60 months). Postoperative knee kinetics were measured, and clinical outcomes were assessed using International Knee Documentation Committee, Lysholm, and Tegner scores. Femoral tunnel widening was measured by comparing postoperative radiographs with final follow-up radiographs. Femoral tunnel width was significantly greater ($P<.001$) and anterior knee translation was significantly higher ($P=.01$) in the transtibial group. Lysholm and Tegner scores were not significantly different ($P>.05$) between the 2 groups. These findings suggest that femoral tunnel widening is associated with increased anterior joint laxity when a direct fixation technique is used for ACL reconstruction, particularly in nonanatomically positioned femoral tunnels. Anatomical femoral tunnel placement provides better anterior stability and less tunnel widening than transtibial tunnel placement; however, these benefits did not produce a detectable advantage in clinical outcomes measures. [Orthopedics. 2017; 40(3):e532-e537.]

Anterior cruciate ligament (ACL) reconstruction is one of the most extensively researched fields in musculoskeletal surgery.¹ The primary goal of ACL reconstruction is the restoration of physiological knee biomechanics and function.² Surgical success usually is attributed to the stability of the grafts in their bony tunnels, providing effective tendon-to-bone healing, and the positioning of the tunnels so that normal physiological knee kinematics are maintained.¹,³,⁴

Stabilization of the femoral graft can be achieved by direct or indirect fixation. Direct femoral fixation can be achieved by using an interference screw or by using any other method that drives the graft into the wall of the bony tunnel. Indirect femoral fixation can be accomplished by passing a pin across the tunnel or by using a button-like device to suspend the graft in the tunnel.

Indirect fixation methods ultimately may provide more rigid fixation, but such methods also may cause more extensive tunnel widening. Although femoral tunnel widening is a relatively common finding...
after ACL reconstruction, it generally is not believed to be associated with inferior clinical outcomes. However, in a prospective randomized trial by Järvelä et al., patients with greater tunnel widening had significantly more anterior and rotational laxity. Regardless of the clinical implications, a widened femoral tunnel can complicate revision surgery.

Good early results have been reported with conventional transtibial femoral tunnel drilling, but osteoarthritic changes usually develop in the long term.6,7 Several studies have shown that knee kinematics are altered by nonanatomical positioning of the femoral tunnel.8-12 Anatomical tunnel position provides superior knee kinematics and results in better postoperative knee function that may in turn prevent early articular degeneration.13-14 The AperFix System (Cayenne Medical Inc, Scottsdale, Arizona) is composed of polyetheretherketone (PEEK) and provides direct fixation. It is biologically compatible and highly resistant to tensile forces.15

This system is believed to improve bone-tendon healing by compressing tendon over bone, increasing the resistance to pullout and decreasing the laxity of the graft in its tunnel.16

There is a substantial body of research reporting the influence of the position of the femoral tunnel on joint laxity, but most of the studies were conducted in patients undergoing secondary fixation methods. The current authors believe femoral tunnel widening may be important in direct graft fixation methods and may play a greater role in determining clinical outcomes than the current literature suggests. It is essential to maintain graft stability in the bony tunnels to avoid joint laxity, and direct fixation depends on firmly driving the graft into the bone. If the tunnel widens, it may be logical to expect instability at the graft-bone interface. However, the relationship between femoral tunnel widening and joint laxity after direct fixation methods is not completely understood, as most of the research has been conducted in patients who underwent ACL reconstruction using indirect fixation methods. Furthermore, the influence of anatomical or nonanatomical positioning of the femoral tunnel on tunnel widening has not been investigated thoroughly.

The current study examined whether (1) the presence of femoral tunnel widening influences anterior joint stability or clinical outcome, (2) the position of the femoral tunnel influences femoral tunnel widening, and (3) whether there are relationships between anatomical and nonanatomical transtibial femoral tunnel position, anterior joint laxity, and clinical outcome. In addition, the clinical and radiographic outcomes of direct femoral fixation using transtibial and anteromedial portal techniques were compared.

**Materials and Methods**

Arthroscopy-assisted primary ACL reconstruction was performed in 89 consecutive patients using the AperFix System between January 2010 and December 2012. The radiographic and clinical outcomes were evaluated retrospectively. Patients with multiligamentous injury, extensive meniscal tears, or cartilage damage were excluded from the study. Patients who underwent previous knee surgery or had a contralateral knee disorder also were excluded from the study. Nine patients who had incomplete data or who were lost to follow-up also were excluded from the study. Consequently, the data of 80 patients (79 men and 1 woman) were analyzed. All surgical procedures were performed by 2 surgeons, and the technique used for creating the femoral tunnel was by personal preference of each surgeon (O. Ozel: anteromedial portal, anatomical; B.Y: transtibial, nonanatomical).

Anatomical femoral tunnel placement was performed via an accessory medial portal in 38 patients (anteromedial group), and nonanatomical femoral tunnel preparation was performed using a transtibial technique in 42 patients (transtibial group). The study was approved by the institutional review board (no. KA13/174), and all patients provided written informed consent.

**Surgical Technique**

All patients underwent diagnostic arthroscopic examination before graft harvesting. Quadrupled hamstring (gracilis and semitendinosus) autogenous grafts were used in all patients. In the anteromedial group, the accessory medial portal was used as part of a 3-portal technique as described by Cohen and Fu.17 In the transtibial group, ACL reconstruction was performed using the transtibial technique described by Morgan et al.18 Femoral tunnel length, width, and implant size were recorded for all patients.

**Rehabilitation Protocol**

All patients underwent the same postoperative rehabilitation protocol involving early continuous passive motion. Proprioceptive exercises, closed chain exercises, and weight bearing as tolerated were started in the third week postoperatively. Postoperative follow-up visits occurred at 6, 12, and 24 weeks after surgery, and then annually thereafter.

Postoperative assessments included KT-1000 arthrometer testing (MEDmetric, San Diego, California) and International Knee Documentation Committee (IKDC), Lysholm, and Tegner scores.19 Femoral tunnel widening was measured by comparing immediate postoperative radiographs with final follow-up radiographs. Femoral tunnel width was measured 1 cm proximal to the articular end as described by Fauno and Kaalund20 (Figures 1-2).

**Statistical Analysis**

The 2 groups were compared using Pearson correlation and independent Student t tests. All data were analyzed using SPSS version 21 software (IBM, Armonk, New York).
Mean follow-up was 40.7 months (range, 27-60 months). There were no significant differences in the demographics or clinical characteristics of the 2 groups (Table 1). The KT-1000 arthrometer results, clinical assessment scores, and femoral tunnel width are summarized in Table 2.

Femoral tunnel widening was significantly associated with anterior joint instability when all of the patients were evaluated as a single cohort ($P<.001$). Clinical outcomes (Lysholm scores) of the entire cohort also were significantly associated with femoral tunnel widening ($P=.02$) (Table 3).

There was no relationship between femoral tunnel widening and anterior joint instability or clinical outcomes in the anteromedial group, but in the transtibial group, there were significant associations between femoral tunnel widening and anterior joint instability ($P=.04$) and clinical outcomes ($P=.01$) (Table 3). Mean femoral tunnel width was significantly greater in the transtibial group ($P<.001$), and anterior knee translation also was significantly higher in the transtibial group ($P=.001$). Clinical outcomes were not significantly different between the 2 groups ($P>.05$) (Table 2).

Anterior knee translation and Lysholm scores were significantly and inversely correlated in the anteromedial group ($P=.004$). This relationship was not observed in the transtibial group (Table 3).

Femoral tunnel width was significantly greater ($P<.001$) and anterior knee translation was significantly higher in the transtibial group ($P=.001$). There was no significant difference in Lysholm and Tegner scores between the 2 groups ($P>.05$) (Table 2).

**DISCUSSION**

Femoral tunnel widening is a well-recognized phenomenon after ACL reconstruction. The possible causes include heat necrosis caused by drilling, graft movement, early aggressive rehabilitation, distance between the fixation points and the articular surface, and nonspecific inflammatory response. Enhanced mechanical stress due to improper graft positioning or acute femoral tunnel angles also is believed to play a role. Nevertheless, femoral tunnel widening usually is not considered among the causes of inferior clinical outcome. However, most of the evidence underpinning this assessment is based on studies of ACL reconstruction that used indirect fixation of the graft to the femur.

It is logical to expect that femoral tunnel widening would impair outcomes after direct rather than indirect fixation, which relies on an intact cortex over the femoral tunnel, or a suspensory mechanism that does not depend on tunnel width. A randomized controlled study has confirmed that anterior and rotational knee laxities are related to femoral tunnel widening with the use of direct fixation for the femoral side.

In the current study, the analysis of the entire cohort indicated anterior knee stability and clinical outcomes were sign-

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Anteromediala Group (n=38)</th>
<th>Transtibialb Group (n=42)</th>
<th>Total (n=80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD, y</td>
<td>29.6±4.3</td>
<td>31.2±5.2</td>
<td>30.4±4.9</td>
</tr>
<tr>
<td>Sex, No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>38</td>
<td>41</td>
<td>79</td>
</tr>
<tr>
<td>Female</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Follow-up, mean (range), mo</td>
<td>36.4 (27-49)</td>
<td>45 (31-60)</td>
<td>40.7 (27-60)</td>
</tr>
</tbody>
</table>

aAnatomical femoral tunnel placement.
bNonanatomical femoral tunnel placement.
nificantly impaired by femoral tunnel widening ($P<.001$, $P=.02$). Although no significant relationship was found between femoral tunnel width and anterior stability or clinical outcome in the anteromedial group, there were statistically significant relationships with both in the transtibial group. This may be explained by the fact that patients in the anteromedial group exhibited significantly less femoral tunnel widening and instability than those in the transtibial group.

There is a relatively limited body of evidence indicating femoral tunnel position influences femoral tunnel widening. Chhabra et al$^{27}$ reported significantly less femoral tunnel expansion with anatomical positioning using an indirect fixation method. In the current study, femoral tunnels were significantly wider in the transtibial (nonanatomical) patients, which may be the result of nonphysiological mechanical forces acting at the graft-bone interface in the nonanatomical femoral tunnel.

The mechanical advantage of anatomical femoral tunnels has been the subject of several studies.$^{12,28,29}$ Although most findings have favored anatomical positioning of the femoral tunnel, the studies have not identified which technique results in better clinical outcome.$^{30-32}$ The AperFix System is a relatively new system for ACL reconstruction that requires direct expandable fixation of autogenous hamstring grafts. The standard interference screw provides direct fixation while delivering unilateral compression and exerting an insertional torque to the graft. The AperFix System provides circumferential graft compression against the bony femoral tunnel without applying insertional torque.

Previous studies with the AperFix System have reported good to excellent outcomes after ACL reconstruction.$^{16,33}$ The majority of these studies were conducted in patients undergoing a transtibial nonanatomical technique. Only a single study by Mulcahey et al$^{32}$ compared anatomical and nonanatomical placement of the femoral tunnel with this reconstruction system. Although the authors found knee stability and clinical outcomes to be similar, the graft source was not uniform. In the current study, anatomical femoral tunnel positioning resulted in significantly better knee stability, but this mechanical advantage did not influence clinical outcomes.

The current study is the first to evaluate femoral tunnel width, location of the femoral tunnel, and anterior knee stability with direct expandable fixation of autologous hamstring grafts. Nonetheless, the current study had several limitations. The study was retrospective and nonrandomized, and because preoperative clinical assessment scores were not available for all patients, postoperative clinical improvement could not be assessed. Although Marchant et al$^{34}$ suggested computed tomography should be used to evaluate femoral bone tunnels, there have been several reports that digital plain radiography is a reliable means of detecting femoral tunnel expansion, with accuracy comparable to magnetic resonance and computed tomography.

### Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Anteromedial Group</th>
<th>Transtibial Group</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel widening, mm</td>
<td>1.2±0.47</td>
<td>3.0±0.9</td>
<td>&lt;.001</td>
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<tr>
<td>KT-1000 arthrometer measurement, mm</td>
<td>2.8±1.8</td>
<td>4.4±2.1</td>
<td>.001</td>
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<tr>
<td>Lysholm score</td>
<td>91.7±9.9</td>
<td>90.6±10.3</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>Tegner score</td>
<td>5.5±1.4</td>
<td>4.7±2.0</td>
<td>&gt;.05</td>
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</table>

*Anatomical femoral tunnel placement.

### Table 3

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Anteromedial Group</th>
<th>Transtibial Group</th>
<th>Entire Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pearson Correlation Coefficient$^d$</td>
<td>$P$</td>
<td>Pearson Correlation Coefficient$^d$</td>
</tr>
<tr>
<td>Tunnel widening–arthrometry</td>
<td>-0.086</td>
<td>.60</td>
<td>+0.301</td>
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<td>Tunnel widening–Lysholm score</td>
<td>-0.218</td>
<td>.18</td>
<td>-0.394</td>
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<td>Lysholm score–arthrometry</td>
<td>-0.462</td>
<td>.004</td>
<td>-0.140</td>
</tr>
</tbody>
</table>

*Anatomical femoral tunnel placement.

$^d$Nonanatomical femoral tunnel placement.

*Positive values denote a directly proportional relationship, and negative values denote an inversely proportional relationship.
mography imaging. In the current study, digital plain radiography was used to evaluate the femoral tunnels as it reduced exposure to radiation and was cost-effective.

**Conclusion**

Femoral tunnel widening was associated with increased anterior joint laxity after ACL reconstruction undertaken with a direct fixation technique, particularly in nonanatomically positioned femoral tunnels. Anatomical placement of the femoral tunnel in direct fixation techniques for ACL reconstruction appears to afford better stability and less widening. Although there was no significant difference in clinical outcome, anatomical femoral tunnel placement rather than transtibial placement is recommended to provide better anterior stability and to avoid excessive tunnel widening.

**References**


30. Koutras G, Papadopoulos P, Terzidis IP, Gigit I, Pappas E. Short-term functional and clinical outcomes after ACL reconstruction with hamstring autograft: transtibial versus antero-


