ABSTRACT: This study evaluates the position of the femoral tunnel, which is achieved using a transtibial, single-bundle anterior cruciate ligament (ACL) reconstruction technique. The radiographs of 50 consecutive, primary single-bundle ACL reconstructed knees using this technique were reviewed. The angle between the femoral tunnel and the apex of the intercondylar notch was recorded. The average angle from the 12-o’clock vertical position to the femoral tunnel was 49° (range, 39°-59.2°; SD = 3.9), corresponding to the 10:20 position on a clock face for a right knee. These results demonstrate that it is technically possible to create an obliquely oriented single-bundle femoral tunnel at approximately the 10:20 position through a tibial tunnel angled approximately 60° from the proximal tibial joint surface. This correlates to a femoral tunnel approximately midway between the anteromedial and posterolateral bundle origins of the ACL.


INTRODUCTION

As the body of orthopedic literature continues to grow in support of various anterior cruciate ligament (ACL) reconstruction techniques and expands our understanding of the biomechanical properties of both the native ACL and the numerous techniques used for ACL reconstruction, it is important to critically evaluate current reconstruction techniques. Techniques for placement of the femoral tunnel have undergone considerable evolution. This article reviews the position of the femoral and tibial tunnels using a transtibial drilled femoral tunnel ACL reconstruction technique and describes technical aspects of the procedure.

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TECHNIQUE

To achieve an oblique femoral tunnel using a transtibial technique, the tibial tunnel must be appropriate to allow the offset femoral guide to be oriented obliquely on the lateral wall of the intercondylar notch. The tibial guide is placed through an accessory inferomedial portal (Figure 1), either through the midpatellar tendon defect when using bone-patellar tendon-bone autograft or through a separate transpatellar tendon portal for allograft reconstructions. Use of the accessory inferomedial portal allows placement of the tibial guide, and thus the tibial tunnel, in an oblique orientation of approximately 60° from the horizontal.

A properly performed notchplasty aids in the placement of the offset femoral aiming guide. The final configuration of the posterior notch should resemble a smooth “Roman arch,” as opposed to a pointed “Gothic arch.” The smooth margin of the notch assists the surgeon in main-
taining the oblique position of the offset aiming guide while drilling the guide pin. The femoral guide pin is placed by maintaining the offset guide in its hooked position and laterally rotating it to place the tunnel even more obliquely on the lateral wall (Figure 2).

After institutional review board approval was obtained, the postoperative radiographs of 50 consecutive (28 right and 22 left) primary ACL-reconstructed knees using a transtibial drilled femoral tunnel and bone-patellar tendon-bone (autograft or allograft) with standard metal interference screws from July 2006 through December 2006 were reviewed. The radiographs were nonweight-bearing anteroposterior (AP) and true-lateral digital images routinely obtained at patients’ 1-week postoperative examinations.

The position of the femoral tunnel on the AP radiograph was recorded in degrees relative to the 12-o’clock or vertical position for both left and right knees using a digital angle measurement tool directly on the images. The average degrees from vertical to the center of the femoral tunnel where it entered the intercondylar notch were calculated for both left and right knees. Similarly, the angle in degrees from a line drawn through the center of the tibial tunnel to a horizontal line drawn from the medial tibial plateau to the lateral tibial plateau was measured on the AP radiographs (Figure 3). All measurement angles were averaged and then translated to the corresponding position on a clock face corresponding to a right knee using a formula whereby each 30° equated to 1 hour on a clock face. For example, a femoral tunnel angle of 30° from vertical translated to right knee clock face position of 11 o’clock; an angle of 45° from vertical corresponded to right knee clock face position of 10:30, or halfway between the 10- and 11-o’clock positions. All clock face positions are reported as viewed for a right knee.

The position of the femoral screw on the AP and lateral radiographs also was recorded following the
The numerical value 1 was defined as the area within the ideal femoral insertion of the ACL on the lateral view. The numerical value 2 corresponded to the area ventral to the ideal femoral insertion of the ACL on the lateral view. The letter “A” was defined as the region on the AP radiograph corresponding to the 10-o’clock to 11-o’clock position of the ACL tunnel. The letter “B” corresponded to a more vertical placement along the intercondylar notch corresponding to the 11-o’clock to the 12-o’clock position. The 12-o’clock position is directly opposite the 6-o’clock position. Average values for each angle are given in degrees.

**RESULTS**

In the frontal plane, the mean angle from the 12-o’clock vertical position to the femoral tunnel was 49° (range, 39°-59.2°; SD = 3.9°), corresponding to approximately a 10:20 clock face position for a right knee. The mean angle of the tibial tunnel to a line paralleling the proximal tibial joint surface was 60.6° (range, 52.5°-74.2°; SD = 4.6°) (Table).

Seventy percent (35 of 50) of the patients in this study were given a score of 1A, indicating ideal placement of the ACL graft in both the sagittal and AP planes. Four of the patients (8%) in this study achieved a score of 1B, which represents ideal position of the ACL graft in the sagittal plane and a vertically oriented graft in the frontal plane. Ten patients (20%) were given a score of 2A, corresponding to ideal frontal placement of the ACL tunnel and a more ventral placement of the graft in the sagittal plane. The remaining patient (2%) had a score of 2B, indicating a vertically oriented graft with ventral placement of the graft in the sagittal plane.

**DISCUSSION**

Increasing numbers of failed ACL reconstructions have been attributed to vertically oriented grafts, with patients complaining of persistent rotational instability and an inability to return to their previous level of athletic activity despite normal AP stability. This common complaint often is demonstrated by a normal Lachman test with a persistent positive pivot shift test. Traditional single-bundle, single-incision ACL reconstruction techniques often have resulted in a vertical or 12-o’clock graft orientation because of the inherent difficulties in placing an oblique femoral tunnel.

Recent studies have shown the importance of the anteromedial bundle for AP stability and the posterolateral bundle for rotational stability. Current trends in ACL reconstruction include using a more obliquely oriented femoral tunnel to place the graft in a more anatomic position on the lateral femoral condyle and provide increased rotational stability. Some surgeons advocate double-bundle ACL reconstruction as a means to restore rotational and translational knee stability by restoring the original anatomy and footprints of the ACL through reconstruction of the anteromedial and posterolateral bundles. This is a difficult technique with evolving support; however, many challenges must be overcome before this technique is widely accepted.

### TABLE

**Femoral and Tibial Tunnel Angles for Trans-Tibial Drilled Anterior Cruciate Ligament Reconstruction**

<table>
<thead>
<tr>
<th></th>
<th>Femoral Angle (°)</th>
<th>Tibial Angle (°)</th>
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<tbody>
<tr>
<td>Mean</td>
<td>49</td>
<td>60.6</td>
</tr>
<tr>
<td>SD</td>
<td>3.9</td>
<td>4.6</td>
</tr>
<tr>
<td>Maximum</td>
<td>59.2</td>
<td>74.2</td>
</tr>
<tr>
<td>Minimum</td>
<td>39</td>
<td>52.5</td>
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**Figure 3.** AP radiograph showing the technique used to measure the femoral tunnel angle (A) relative to the vertical 12-o’clock position and the tibial tunnel angle (B) relative to the proximal tibial joint surface. Note the clock face roughly overlies the intercondylar notch, with the 6-o’clock position at the bottom edge at the same level as a line drawn between the inferior margins of the lateral and medial femoral condyles. The 12-o’clock position is directly opposite the 6-o’clock position.
The observations of this study support the hypothesis that the long-standing clinical success of the principal investigator (B.R.B.) can be attributed to an oblique femoral tunnel placement in ACL reconstruction, which incorporates the normal anatomic footprint of the anteromedial and posterolateral bundles and provides patients with adequate translational and rotational knee stability. Sommer et al\(^\text{10}\) demonstrated that femoral placement of the ACL graft can be defined easily on lateral and AP radiographs. They found the most common error of femoral tunnel positioning was tunnel placement anterior and vertical to the anatomical insertion of the ACL. Using this method of radiographic ACL graft measurement, 90% of the ACL grafts were placed in an ideal, oblique position in the AP plane and 78% of the grafts were placed in an ideal position along the posterior border of the Blumensaat line in the sagittal plane. Our results also are supported by the conclusion of Simmons et al\(^\text{9}\), who demonstrated that the angle of the femoral tunnel and the ACL graft tension is controlled by the tibial tunnel orientation and that the ideal orientation of the tibial tunnel to minimize ACL graft tension in flexion is at an angle of 60° to the horizontal.

One inherent weakness of this study is that tunnel and screw position measurements may not necessarily correlate with the precise location of the femoral and tibial tunnels, as they represented indirect measurements of their radiographic locations. It often is difficult to determine the precise location and orientation of the tunnels because of the technical limitations of the radiographs. However, digital radiography allows for adjustment of contrast and brightness levels, which can improve visualization of the tunnel location.

The technique described by Sommer et al\(^\text{10}\) for determining graft position has several limitations. As the femoral screw typically is placed anterior to the femoral bone plug, many of the 10 cases scored as a 2A (ideal frontal placement but more ventral than ideal on the lateral view) represented acceptable tunnel placement, in which case the percentage of cases with ideal positioning of the femoral screw in both the frontal and sagittal plane was likely higher than what we reported. Similarly, the femoral screw also may have appeared more vertically oriented in the coronal plane as it pushed the graft laterally within the femoral tunnel. In addition, this technique originally was based on criteria as measured on a flexed knee, or tunnel view, which was not available for this study as the standard postoperative radiograph protocol used by the senior author (B.R.B.) does not include the use of the tunnel radiographic view.

No previous studies have confirmed oblique femoral tunnel placement through radiographic studies. This study provides objective radiographic data that a consistent, oblique femoral tunnel at approximately the 10:20 position on the clock face for a right knee is possible using a transtibial drilled femoral tunnel, provided the tibial tunnel is placed at approximately 60° relative to the proximal tibial joint surface.

REFERENCES