Measurement of Anterior Cruciate Ligament Angles in Single-Bundle Reconstruction Using the Anteromedial Portal

Xuesong Dai, MD, PhD, and Youzhi Cai, MD

Abstract

The purpose of this study was to measure the graft angles of reconstructed anterior cruciate ligament (ACL) with anteromedial (AM) portal technique in single-bundle reconstruction.

Between October 2007 and October 2009, a total of 53 consecutive patients receiving arthroscopic ACL reconstruction with AM portal technique were enrolled in this cohort study. The placement of ACL femoral tunnel was within the femoral footprint of ACL. All the patients underwent postoperative computed tomography scan, magnetic resonance imaging, and radiological examinations, as well as clinical evaluations. Both knees of these patients were measured to compare the ACL angles.

The mean sagittal ACL angle in operated knees was 52.88°±2.78°, compared with 51.89°±1.95° in the contralateral knees (*P*>.05). The mean ACL-Blumensaat line angle was 4.96°±0.77° in operated knees and 4.49°±0.83° in contralateral knees (*P*>.05). The computed tomography value (32.8%±5.6%) was also close to the position of the native femoral tunnel.

Drilling the femoral tunnel through the AM portal can place the entry point of femoral tunnel precisely in the footprint, resembling the orientation of a native ACL.

Anterior cruciate ligament (ACL) graft positioning is considered a key factor for proper postoperative knee function and restoration of the physiologic kinematics of the femorotibial joint in ACL reconstruction.[1,2] Some argue that anatomic reconstruction of the ACL not only diminishes the anterior-posterior translation (APT), but also influences the rotation stability.[3,4] According to several anatomical studies, femoral attachment of the ACL lies deep and low on the medial wall of the lateral femoral condyle,[5,6] and the native ACL does not obey the rules of isometry.[7-9] Musahl and colleagues[10] found that a femoral tunnel position inside the anatomical footprint of ACL results in knee kinematics closer to the intact knee than a tunnel position located for best graft isometry. This suggests that grafts functionally centered within their footprints may provide the better opportunity for normal motion in the reconstructed knee.

Clinical displacement of the tunnels can result in decreased range of knee motion or increased APT and knee instability and the impingement of the graft against the intercondylar notch or against PCL.[10-13] In particular, the femoral tunnel is the most commonly displaced.[14] The femoral attachment site has greater effect than tibial attachment on graft length changes as the knee flexes and extends,[15] and even minimal displacement of the femoral attachment along the Blumensaat's line is particularly significant.[11,16] Nonanatomically placed graft is subject to abnormal tensile and compressive load, which consequently affects the ligamentization process of graft healing.[17]

The femoral tunnel position tends to be placed in the femoral footprint of the ACL, which is posterior to the so-called over the top position.[18-20] How to make the femoral tunnel within the anatomical footprint of the ACL is a critical issue. Two different approaches for drilling the femoral tunnel are commonly used in single-bundle ACL reconstruction, drilling through the tibial tunnel (transtibial [TT] technique) and drilling through the anteromedial portal (anteromedial [AM] portal technique). The latter technique has been reported to be clinically associated with an improved subjective and objective stability of the knee joint.[21] The location of the femoral tunnel is restricted by the angulation of the tibial tunnel when using the transtibial drilling technique.[22-24] However, by placing the femoral tunnel through the AM portal, which was first published by Bottoni and colleagues,[25] drilling is no longer constrained by the orientation of the tibial tunnel and the surgeon is able to independently choose the optional femoral tunnel position under arthroscopic visualization of the native ACL footprint.[24,26]

In the present study, we performed a postoperative measurement of the anatomical reconstruction of single-bundle ACL using the AM portal technique. We hypothesize that drilling of the ACL femoral tunnel through the

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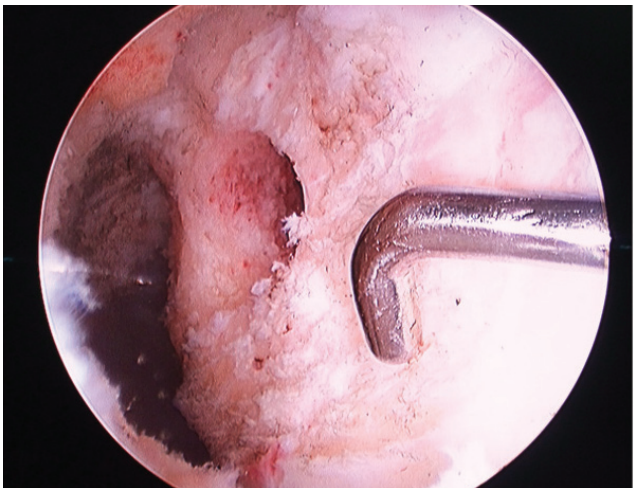

Figure 1. Arthroscopic view of bone tunnel position on the medial wall of lateral femoral condyle of left knee.

AM portal would closely approximate the native ACL alignment. We tested this by measuring the graft angles of reconstructed ACL's and comparing them to the contralateral native ACL with 4 imaging techniques.

Materials and Methods

One hundred and five patients with a single ACL rupture underwent arthroscopic ACL reconstruction by 1 surgeon with either autograft or allograft between October 2007 and October 2009. Of these patients, a subgroup of 53 patients who underwent ACL reconstruction with the AM portal technique, with or without meniscal tear, was chosen. At the time of surgery, the surgeon was not aware of the postoperative tunnels and grafts being evaluated. All patients were operated at our institution. Patients who underwent other major operations in the affected knee were excluded from the study. The patients included in the study gave consent to receive postoperative magnetic resonance imaging (MRI) and computed tomography (CT) scan of their operated knees and the intact ACL of their contralateral knees. Patients were aware that the data would be used for scientific purposes.

Surgery

The femoral tunnel was drilled through an AM portal, which is 1 cm medial to the patellar tendon and just distal to the inferior pole of the patella. The endoscopic guide pin (diameter, 2.0 mm) was placed just at the center of the femoral footprint of the AM bundle, which was located roughly 5 mm anterior to the most posterior aspect of the medial wall of the lateral femoral condyle at a 90° flexion, or the 2- to 2:30-o'clock position on the left knee. The knee was flexed to 120° and the pin was drilled through the lateral femoral condyle. The endoscopic cannulated drill was drilled to the appropriate depth (Figure 1). Graft fixation was accomplished using an Endobutton (Smith & Nephew, Boston, Massachusetts) on the femoral side and interference screw on the tibial side.

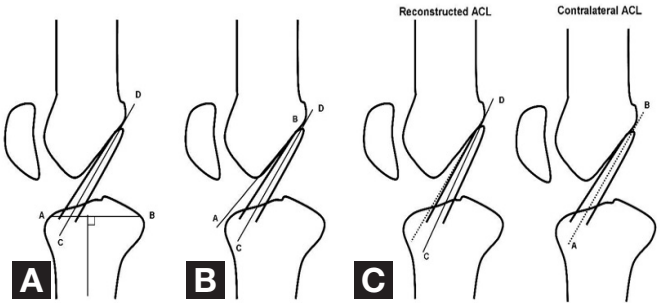

Figure 2. (A) The ACL angle is formed by the intersection of 2 lines: one parallel to the centerline of the graft in the sagittal plane; the other is perpendicular to the long axis of the tibia. (B) The ACL-Blumensaat line angle is formed by 2 lines: one parallel to the centerline of the graft in the sagittal plane; the other parallel to the intercondylar roof. (C) The relative ACL angle was defined between 2 lines: one parallel to the centerline of the graft in the sagittal plane, and a reference line parallel to the native ACL on the contralateral side.

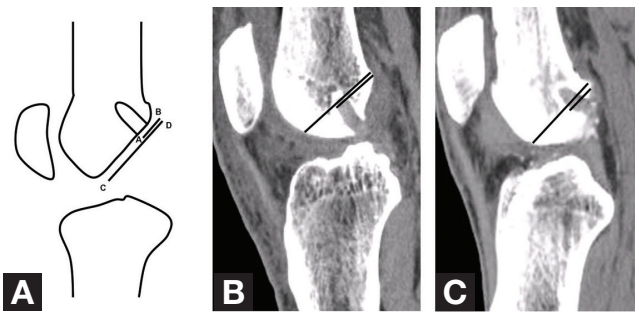

Figure 3. (A) Measurement of femoral bone tunnel position was illustrated; (B) CT image shows an anterior placement of femoral tunnel; and (C) CT image shows an appropriate placement of femoral tunnel.

MRI Measurements

A 3.0-Tesla MRI (Siemens Company, Munich, Germany) was used for all patients when their knees could be fully extended postoperatively. The main knee imaging protocol included the sagittal plane. The knee was positioned in full extension with approximately 15° of external rotation. Each measurement was carried out on the single sagittal image that showed the major portions of the ACL within joint. All the measurements were performed on a Digimizer 3.0 (MedCalc Software, Mariakerke, Belgium) and an automated computer calculation was carried out for the distance and angle. Two orthopedic residents worked on the MRI evaluation retrospectively without any knowledge of the arthroscopic findings, clinical history, or initial MRI interpretations. The orientation of the ACL was measured using 3 different methods (Figure 2): the sagittal ACL angle, the ACL-Blumensaat line angle, and the relative ACL angle. The sagittal ACL angle was defined between a parallel line to the ACL graft and a reference line parallel to a line perpendicular to the long axis of the tibia (Figure 2A). The ACL-Blumensaat angle was defined as the angle between the posterior surface of the femur (Blumensaat line) and the parallel line to the ACL (Figure 2B). The relative ACL

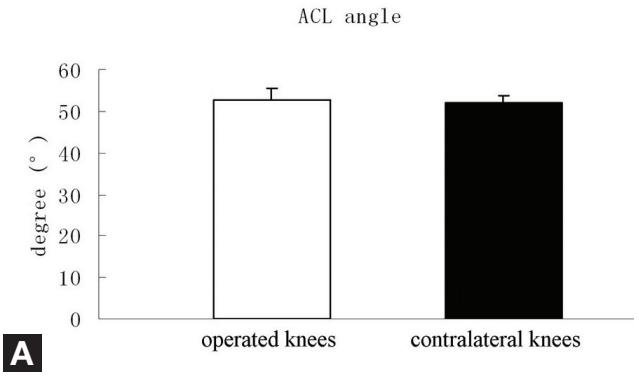

Figure 4. (A) Mean anterior cruciate ligament (ACL) angle for the operated knee and the contralateral knee (*P*>.05). (B) Sagittal magnetic resonance imaging scans shows that the angle of ACL graft resembles the native ACL on the contralateral knee.

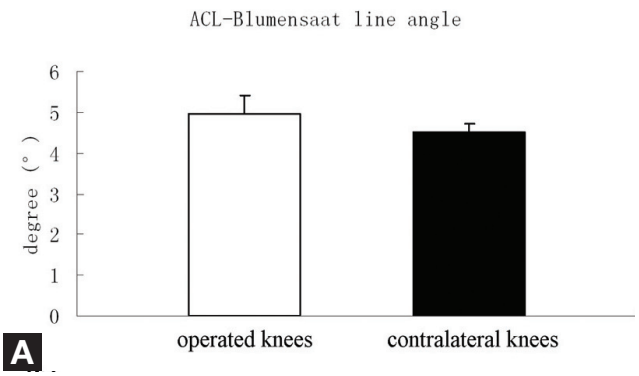

Figure 5. (A) Mean anterior cruciate ligament (ACL)-Blumensaat angle for the operated knee and the contralateral knee (*P*>.05). (B) Magnetic resonance imaging shows the ACL-Blumensaat angle of the operated and contralateral knee.

angle was defined between a parallel line to the ACL graft and a reference line parallel to the opposite native ACL in the same station (Figure 2C).

CT Measurement

A CT scan of the knee was performed on each knee with the knee positioned in full extension.[20] On the sagittal reconstructions, the roof of the notch was taken as the representation of BL. The most lateral slice that showed the roof and the tunnel was taken for the measurement of the Z value. If roof and tunnel were not seen on the same slice, the measurement was rated as impossible. We used the anterior tunnel wall as the measurement point; low values represent a deep and posterior position of graft placement. Zct is expressed as a percentage of the total length of BL (Zct = AB/CD) (Figure 3). We compared the value to what is assumed to be the correct femoral tunnel position (ie, 31.03%±1.8%), according to Hoser and colleagues[20] in a cadaver study. The graft's insertion site on the medial wall of the lateral condyle was reconstructed by the three-dimensional (3D) CT scan.

Statistical Analysis

The statistical comparison was made using a one-factor analysis of variance. All statistical analyses were carried out using SPSS software (SPSS for Windows Release 12.0, SPSS Inc, Chicago, Illinois). All analyses were set at the 95% confidence interval for statistical significance.

Results

MRI Results

The mean sagittal ACL angle in the operated knees and contralateral knees was 52.88°± 2.78° and 51.89°± 1.95°, respectively (Figure 4). The mean ACL-Blumensaat line angle was 4.96°±0.77° and 4.49°±0.83°, respectively (Figure 5). The mean relative ACL angle was 0.82° ± 0.09°. There was no significant difference in the mean sagittal ACL angle and mean ACL-Blumensaat line angle between both knees. The 95% confidence intervals for the independent measurements of each parameter were similar for both reviewers and the measurements were reproducible.

CT Results

Analysis according to the method used by Hoser and colleagues,[20] only 40 cases were included due to invisible bony marks that virtually made the calculation impossible in 13 cases, produced an average value of 32.8%±5.6% (range, 22.2% to 39.6%) for distance AB to CD (Figure 3), compared with the native femoral tunnel (31.03%±1.8%) suggested by Hoser. A 3D CT photograph showed the femoral tunnel centered in the femoral footprint of the ACL drilled from the AM portal (Figure 6).

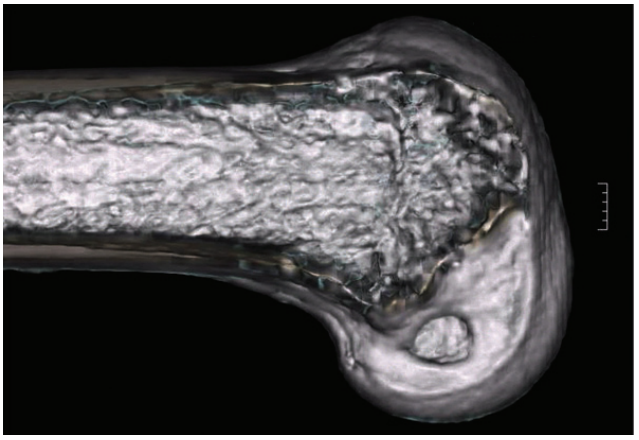

Figure 6. A three-dimensional computed tomography image showing the appropriate femoral attachment site of the anterior cruciate ligament graft.

Discussion

Although there have been many reports on the single-bundle ACL construction, there are few reports on the status of the reconstructed ligament, such as the graft orientation and tunnel placement in clinical patients.

Traditionally, arthroscopic ACL reconstruction is performed using a TT technique.[27,28] Data suggest that 85% of American orthopedic surgeons who were members of the American Orthopaedic Society for Sports Medicine were using the TT technique and 15%, the AM portal technique.[29] The arthroscopic TT technique has been an advance which is aimed at limiting extensor mechanism trauma,[30] decreasing the amount of scarring in the knee, and avoiding exposure of the articular cartilage.[31-33] However with transtibial drilling, the ACL grafts were prone to be placed more vertical than normal and there was difficulty in drilling femoral tunnel within the anatomical ligament insertion site (ie, the footprint). Cain and Clancy[34] found that when ACL graft was more vertical and not centered in the anatomical femoral footprint, it could result in residual pivot shift, although APT can be restored. Lee and colleagues[35] reported that in a subset of patients with a vertically oriented graft, pivot shift test and Lysholm score were significantly worse, compared with patients with a more oblique graft placement. It may result in insufficient rotational stability since the graft is placed close to the rotational axis of the knee. Moreover, several studies demonstrated that transtibial femoral tunnel drilling could not reach the anatomical site of the ACL insertion at the 2-o'clock position.[5,36] Usually with this technique, a position corresponding between the 12- and 1-o'clock position (left knee) could be reached and the graft is placed in a relatively vertical position.[37,30] Thus, the reproduction of the orientation of the native ACL in the sagittal plane using this TT technique was hard to achieve.

We found that a change to more oblique graft orientation in the femoral tunnel placement resembles native ACL in different objective assessments. This position was reported to be clinically associated with an improved subjective and objective stability of the knee joint.[27] According to biomechanical investigations,[12,38] the oblique 2-o'clock position is better than the 1-o'clock position to restore rotational knee stability. Furthermore, 2 studies reported that the AM portal technique decreases graft tension and minimizes graft/PCL impingement during full flexion, compared to the TT technique.[39,40]

Given the nature of a basic science study, we cannot claim the clinical benefits with this method in terms of rotation stability and late morbidity of arthritis, therefore, long-term randomized contrast studies are needed in the future.

From a clinical viewpoint, the femoral tunnel tends to be shorter with AM portal approach, which may potentially affect the bone-tendon healing. The Endobutton was always used on the femoral side in our group for fear that the interference screw could deflect the insertion site from the center of the footprint. Additionally, it is also hard to argue that our technique—which aimed to place the femoral tunnel insertion more posteriorly and within the so-called footprint—is necessarily an "anatomic" reconstruction. Since a true anatomic reconstruction, as we perceive it, should include not only the orientation of the graft, but the full coverage of footprint by the graft, the correct tension, and even a close-to-normal shape of the graft. However, our study has the advantages of a consecutive series of patients, operated by the same surgical team using the same graft and fixation technique. In addition, MRI and CT scan were chosen as the accurate imaging modality to evaluate graft position and orientation.

Conclusion

Drilling the femoral tunnel through the anteromedial arthroscopy portal enables the placement of the femoral tunnel within the ACL footprint independently. The orientation of reconstructed graft closely resembles that of the native ACL. Future studies are needed to look into the mid-term or long-term clinical outcomes using the AM portal drilling technique.

Authors Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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