Femoral Tunnel Positioning in Anterior Cruciate Ligament Reconstruction: Anteromedial Portal versus Transtibial Technique—A Randomized Clinical Trial

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Abstract

Purpose The purpose of this study was to investigate, through three-dimensional computed tomography (3D-CT), the accuracy of femoral tunnel positioning in patients undergoing anterior cruciate ligament (ACL) reconstruction, comparing transtibial (TT) and anteromedial (AM) techniques.

Methods We evaluated postoperative 3D-CT scans of 26 patients treated with ACL reconstruction with hamstrings autograft using a low accessory AM portal technique and 26 treated with the TT technique. The position of the femoral tunnel center was measured with the quadrant method.

Results Using quadrant method on CT scans, femoral tunnels were measured at a mean of 32.2 and 28.1% from the proximal condylar surface (parallel to Blumensaat line) and at a mean of 31.2 and 15.1% from the notch roof (perpendicular to Blumensaat line) for the AM and TT techniques, respectively.

Conclusion The AM portal technique provides more anatomical graft placement than TT techniques.

Level of Evidence Level I, randomized clinical study.

Keywords
- anterior cruciate ligament
- reconstruction
- femoral tunnel
- anteromedial portal
- transtibial
- computed tomography

Introduction

Improper placement of bone tunnels is a major reason for anterior cruciate ligament (ACL) reconstruction failure.[1–5] Several cadaveric and clinical studies have focused on the anatomical tunnel placement in ACL reconstruction to better restore normal knee kinematics and to improve rotatory stability and long-term outcome.[6–9] Harner et al[10] introduced the anteromedial (AM) portal technique for femoral tunneling to obtain a low-oblique drilling, which should be more anatomic than the traditional transtibial (TT) technique.

Different techniques were described to identify the center of femoral footprint,[11–14] albeit most of the studies failed to adequately describe tunnel position. Kopf et al[15] stated that three-dimensional computed tomography (3D-CT) is a reproducible and precise method to measure bone tunnel femoral position in ACL reconstruction. However, there is no clear information regarding 3D-CT evaluation of femoral tunnel position in the TT and AM portal techniques for femoral tunnel placement in ACL reconstruction.

The purpose of this study was to compare the position of femoral tunnel through 3D-CT in patients undergoing ACL

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reconstruction using the TT versus AM portal technique. The hypothesis of the study was that 3D-CT measurement of femoral tunnel position can reveal a significant difference between the AM and TT tunnel placement techniques.

Methods

We conducted a prospective randomized study to evaluate femoral tunnel position in patients undergoing ACL reconstruction with two different techniques (TT and AM techniques), with 3D-CT scan performed 20 days after surgery.

Participants

Between January 2012 and June 2014, 52 patients who were diagnosed with ACL rupture underwent primary ACL reconstruction using autologous hamstring tendon grafts. Diagnosis of ACL rupture was based on clinical diagnostic criteria summarized as follows: history of knee traumatic accident; subjective perception of knee laxity/instability; clinical evaluation (jerk test/pivot shift test, Lachman test); and magnetic resonance imaging (MRI) scan positive for complete ACL lesion.

Patients were randomly divided in two groups: 26 treated using an AM portal (group AM) and 26 using the TT technique (group TT). The randomization was performed by a statistical software before the beginning of the study. Group AM consisted of 20 men and 6 women with a mean age of 25.2 years (range: 16–40 years). Group TT consisted of 18 men and 8 women with a mean age of 26.4 years (range: 16–40 years). The surgery was performed on the right knee in 18 and 16 and on the left knee in 8 and 10 patients for groups AM and TT, respectively. The purpose of the study and the experimental procedures were explained to all the patients before they gave their written consent to participate.

Surgical Technique

In both the surgical procedures, the semitendinosus and gracilis tendons were harvested (from the affected limb) and prepared as a double-loop (four-stranded) graft.

In the TT ACL reconstruction, a tibial tunnel was created using an ACL tibial guide set at an angle of 55 degrees, with the tip of the tibial guide positioned at the central portion of the original ACL. The femoral tunnel was made using the TT technique at 1.30 to 2.00 o'clock position for the left knee and 10 to 10.30 o'clock position for the right knee.

In the AM ACL reconstruction, accurately placed portal was necessary. After formation of routine AM and AL portals, a central portal (through the fibers of the patellar tendon) and a low accessory AM portals were established (through arthroscopic view). The central portal is useful for the correct visualization of the femoral footprint; the low accessory AM portal is necessary to ensure adequate access for lateral tunnel drilling—since it lies close to the medial condyle, it is important to take attention to avoid iatrogenic cartilage damage. Using the lateral intercondylar ridge and the original femoral footprint as landmarks, we performed the femoral drilling.

In both groups, an EndoButton CL Ultra-Fixation (Smith & Nephew, Andover, Massachusetts, United States) was used for femoral fixation; the grafts were pretensioned using a commercial tensiometer for 5 minutes on the tendon preparation board, followed by a maximal manual pull flexing and extending the knee through 15 cycles of full motion. Tibial fixation was granted by a bioabsorbable screw (BIORCI-HA, Smith & Nephew) and a metallic staple.

Outcome Measurements

A postoperative 3D-CT was performed in all patients 20 days after surgery, obtaining femur and tibia reconstruction without soft tissue. Measurements were performed twice by an orthopaedic surgeon on two separate occasions to assess intraobserver reliability.

The femoral tunnel position was measured according to the quadrant method suggested by Bernard et al,[14] obtaining a mediolateral view of the lateral femoral condyle in a strictly lateral position from the 3D-CT. The location of the tunnels was presented as the percentage distance from the intercondylar notch roof and quantified from the deepest subchondral contour to the center of the tunnel. The image was enclosed with a rectangular measurement frame (a 4×4 grid) formed by the Blumensaat's line, a parallel line tangent to the most inferior margin of the lateral condyle and two perpendicular lines tangent to the deepest/shallowest subchondral contour of the lateral femoral condyle.

The central point of the tunnel (k) was calculated as a/t and b/h, where t is the total sagittal diameter of the lateral femoral condyle along Blumensaat's line, a is the distance of k from the deepest subchondral contour, h is the maximum intercondylar notch height, and b the distance of k from Blumensaat's line. The ratios of a/t and b/h were expressed as percentage (►**Fig. 1**).

Postoperative Treatment

Both groups underwent the same standardized rehabilitation program with regular follow-ups. All patients were allowed for progressive weight-bearings with crutches (no brace). An early start to quadriceps exercises has been applied to improve early ROM development. With this protocol, patients gained full range of motion in 2 to 4 weeks, with an effective participation of the patient in the following rehabilitation phases. Balance and proprioception training, started early in the postoperative period, facilitate a positive effect on joint position sense, muscle strength, experienced knee function, and return to full activity. Closed chain exercises have been introduced in early rehabilitation, with benefits such as stimulation of proprioceptors, reduction of shear and acceleration forces, and development of dynamic knee stability; we consider closed-chain exercises safer and more functional than open-chain exercises.

All patients were supervised two to three times a week to assure that the correct quality of performance and level of difficulty was achieved.

With this protocol, patients return to sport activities 6 months after surgery.

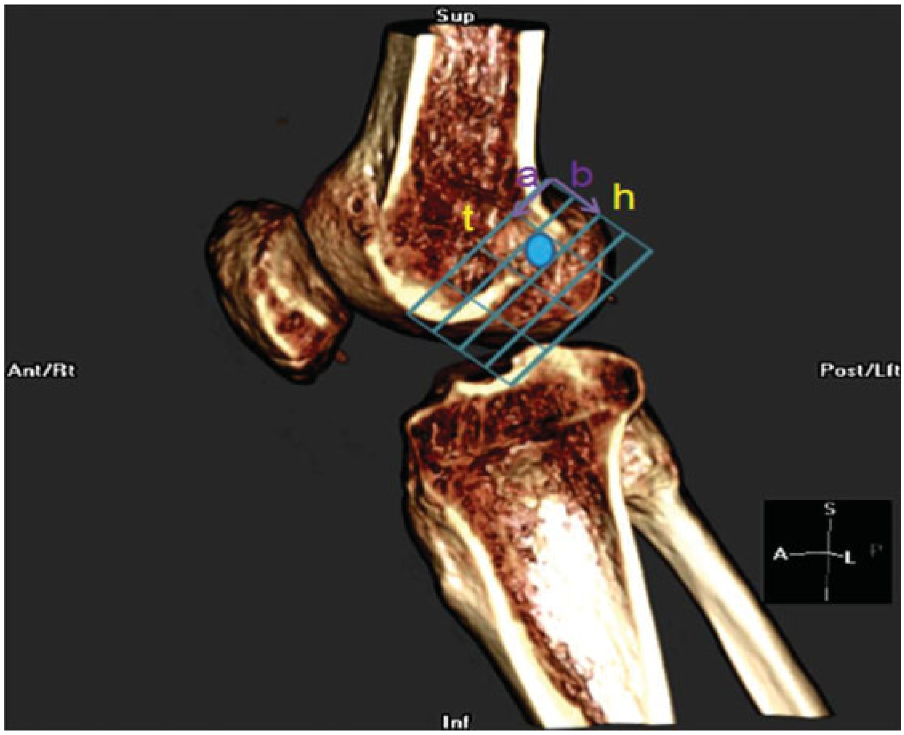

Fig. 1 Quadrant method according to Bernard et al.[14] A rectangular 4 × 4 grid is drawn over the mediolateral view of the lateral femoral condyle in strictly sagittal sequence from three-dimensional computed tomography. t, Blumensaat's line; h, maximum intercondylar notch height; a, distance of femoral tunnel center from the deepest subchondral contour; b, distance of femoral tunnel center from Blumensaat's line.

Data Analysis

The sample size calculation was performed basing on the assumption that the main measurement (femoral tunnel position) is continuous and fairly normally distributed and that a 20% difference in the outcome measures is clinically relevant. With a significance level of 5%, at least 20 participants per group were needed to be included.

Statistical analysis was performed using SPSS software (SPSS Inc., Chicago, Illinois, United States). *t*-tests were performed to compare TT and AM techniques tunnel position in a/t and b/h measures. To account for the comparisons of the femoral tunnels, the significance level was set at $p < 0.001$. Data were presented as mean value ± standard deviation.

Results

Measurement of femoral tunnel placement from the subchondral contour of the lateral femoral condyle (*a/t*) was 32.2 ± 3.3% and 28.1 ± 1.6% for the AM and TT groups, respectively (►**Fig. 2**).

Measurement of femoral tunnel placement from the Blumensaat's line (*b/h*) was 31.2 + 1.7% and 15.1 + 1.9% for the AM and TT groups, respectively (►**Fig. 3**). Differences were significant in all comparisons ($p < 0.0001$).

Discussion

The purpose of this study was to evaluate femoral tunnel positioning in ACL reconstruction with 3D-CT using two different techniques (AM and TT techniques). Most studies

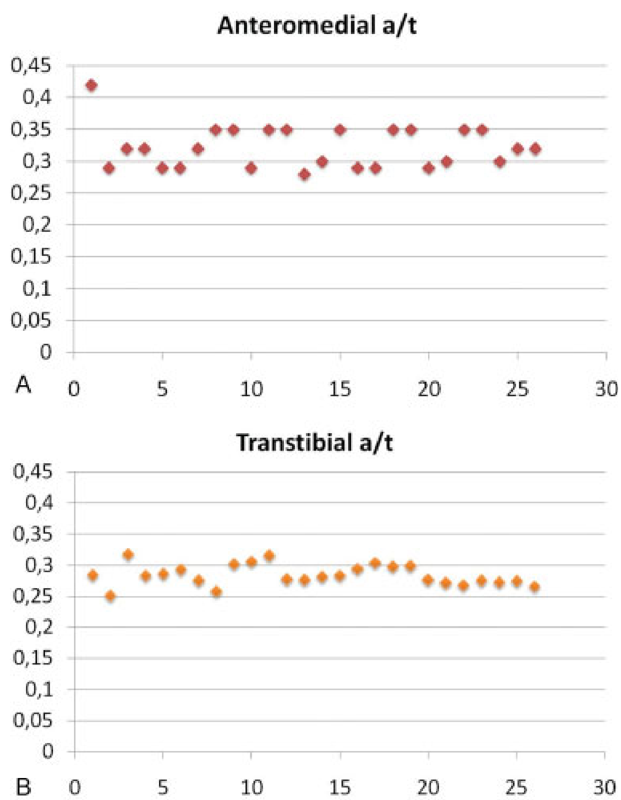

Fig. 2 Graph of *a/t* measures in the anteromedial group (A) and in the transtibial group (B).

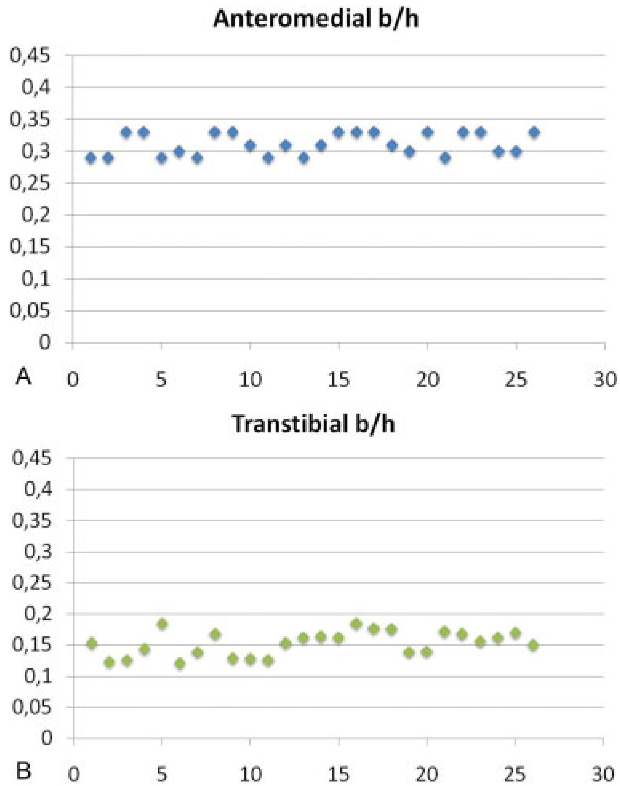

Fig. 3 Graph of *b/h* measures in the anteromedial group (**A**) and in the transtibial group (**B**).

have recently focused on the importance of restoring the anatomical characteristics of natural ACL; nonanatomical orientation of the graft can affect knee function with pain and instability, where a more vertical tunnel orientation can be correlated with rotatory instability, graft rupture, and poor outcomes.[5,8,12,15–23] Techniques for restoring anatomical femoral footprint have been reported in AM reconstructions, such as out-in and in-out techniques.[10,11,24–29] There are also previous studies claiming the plausibility of achieving anatomical femoral insertion site even using a TT technique.[30] Heming[31] commented that the tibial tunnel length must be shortened with a starting point closer to the joint line to obtain an accurate positioned footprint. Lee et al[30] recently described a modified TT technique for single-bundle ACL reconstruction with the purpose of providing a more anatomical placement of the femoral tunnel.

Evaluating the tunnel position with traditional postoperative radiographs after ACL reconstruction is commonly known to be inaccurate because of the tunnel location within the 3D notch.[32–34] Thanks to recent progresses in imaging tools and softwares, 3D-CT can provide high accuracy in visualization of bone structures.[32–34] Three-dimensional assessment of the tunnel position gives accurate quantification of angles and diameters. Furthermore, the selective rotation of the model view (with the possibility of removing sections of bone) allows a clear visualization of regions traditionally difficult to see.[32–34] In 2011, Meuffels et al[32] compared plain radiographs, CT scans, and 3D reality imaging techniques, confirming that CT scans and 3D virtual reality images were more reliable than radiographs (higher intra- and interobserver agreement).[34,35]

The most common method used to assess femoral tunnel position is the quadrant method. Bernard et al[14] reported that the center of the femoral insertion of ACL (in human cadaveric knees) was located at 24.8% of the distance *t* measured from the deepest subchondral contour and at 28.5% of the height *h* measured from Blumensaat's line. The values were 30.35 and 29.95%, respectively, according to Tsukada et al,[36] 26.9 and 27.5%, respectively, according to Steckel et al,[37] 23.9 and 37.95%, respectively, according to Zantop et al,[19,24] 27 and 29%, respectively, according to Yamamoto et al,[17] and 26.6 and 30%, respectively, according to Lee et al.[16]

The results of our study showed that *a*/*t* was 32.2 and 28.1% whereas *b*/*h* was 31.2 and 15.1% for the AM and TT techniques, respectively. These results confirm previous evaluations by other authors,[18,25,38] who reported a higher or more anterior position than the natural ACL femoral footprint using a TT technique. Dargel et al[39] reported suboptimal femoral tunnel position, whereas Giron et al[40] reported the technical impossibility to restore femoral origin using a TT technique despite any modification as confirmed by Kopf et al.[15,33]

There are some limitations in this study. First, the role of the angle between the femoral tunnel and the graft was not taken into consideration. Second, no clinical outcomes were considered, such as stability and functional scores. Finally, the sample size was small.

In conclusion, the AM portal technique provides more anatomical graft placement than TT techniques in ACL reconstruction. This study provided analysis by 3D-CT models, a reproducible and precise method of measuring and demonstrating bone tunnel position.

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