Gravity Reduces the Tibia When Using a Tibial Guide That Targets the Intercondylar Roof

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Background: Reduction of the tibia relative to the femur with the knee in maximum extension is required to correctly position the tibial tunnel in the sagittal plane when using a guide that targets the intercondylar roof. The authors found no studies that determined (1) whether gravity reduces the tibia and (2) whether roof impingement is prevented without a roofplasty and without positioning the tibial tunnel too posteriorly.

Methods: The position of the tibia relative to the femur was measured from a lateral radiograph of the treated knee in maximum extension with and without the tibial guide and of the contralateral normal knee in extension in single-leg stance (control).

Results: The position of the tibia with and without the tibial guide was not different (P = .33, not significant) and was only 0.7 mm more posterior than the control knee (P = .0075). A roofplasty was not required, and the clearance was 2 mm or less.

Conclusion: Gravity reduces the tibia on the femur when using a guide that targets the intercondylar roof. The use of a tibial guide that targets the intercondylar roof prevents roof impingement without a roofplasty and without positioning the tibial tunnel too posteriorly.

Keywords: anterior cruciate ligament (ACL); tibial tunnel

Anatomical placement of the tibial tunnel without roof impingement and within the pathway of the intact ACL is critical to the success of an ACL reconstruction because roof impingement causes extension loss, increased anterior laxity, effusions, and anterior knee pain.[14,17,21,24] The ACL graft is placed without roof impingement and is anatomically positioned when the anterior wall of the tibial tunnel is posterior and adjacent to the slope of the intercondylar roof with the knee in maximum extension.[14] Placing the tibial tunnel more posteriorly and in a nonanatomical position causes a loss of strength and stiffness in the ACL graft.[3] Placing the tibial tunnel anterior to the slope of the intercondylar roof requires a roofplasty to prevent roof impingement, a roofplasty being the incremental removal of bone from the intercondylar roof until there is 1 to 2 mm of clearance between the graft and roof with the knee in maximum extension.[8,10]

Several studies have shown that removal of bone from the roof and wall of the intercondylar notch is not benign.[8,19] A roofplasty increases anterior translation,[8] operative time, and intra-articular bleeding. A roofplasty and wallplasty increase the mean intra-articular pre-tension in the graft required to restore normal anteroposterior laxity and increase anterior laxity.[19] Therefore, placement of the tibial tunnel so that roof impingement is prevented without a roofplasty and without positioning the tibial tunnel too posteriorly would be an important goal of a tibial guide.

The present study evaluates the use of a tibial guide that targets the intercondylar roof. The use of such a guide requires that the tibia is reduced with respect to the femur in the sagittal plane. To our knowledge, no study has determined whether the tibia is reduced on the femur when this type of guide is used or whether the reduction is caused by gravity or manipulation of the guide. We hypothesize (1) that gravity reduces the tibia in a knee with a torn ACL (that may also have a meniscal tear and a tear of the collateral ligament that does not require repair) and (2) that the use of a tibial guide that targets the intercondylar roof prevents roof impingement without a roofplasty and without positioning the tibial tunnel too posteriorly.

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One author has a commercial affiliation with a product named in this study.

The American Journal of Sports Medicine, Vol. 32, No. 7
DOI: 10.1177/0363546503262645

MATERIALS AND METHODS

Overview

Eight subjects with a torn ACL were examined to determine whether the tibia's position on the femur differed when comparing the position of the tibia on the femur with and without the guide. Fourteen subjects (including the previous 8) were examined to determine whether the tibia was reduced by comparing the position of the tibia on the femur in the contralateral normal knee in extension in a single-leg stance with the treated knee with the tibial guide and guidepin in place. Subjects with a tear of the PCL, medial collateral ligament (MCL), or lateral collateral ligament that required open repair were excluded.

Technique for Using a Tibial Guide That Targets the Intercondylar Roof

The patient, who was under a general anesthetic, was placed in a supine position on the operating table (Figure 1). A tourniquet was placed about the thigh. A leg holder was clamped to the operating table, and the foot of the operating table was flexed 90°. The proximal thigh was clamped in a leg holder.

Arthroscopic portals were placed with the knee in 90° of flexion. A modified anteromedial portal was made next to the medial edge of the patellar tendon, through which instruments and the tibial guide that targets the intercondylar roof were inserted. A transpatellar tendon portal was made at the junction of the lateral one third and medial two thirds of the patellar tendon, through which the arthroscope was inserted. The knee was inspected, and any meniscal tears were excised or repaired. The remnant of the torn ACL was excised.

With the knee in flexion, the tibial guide (65 Degree Howell Tibial Guide, Arthrotek Inc, Warsaw, Ind) was inserted through the modified anteromedial portal. An attempt was made to place the 9.5-mm-wide tip of the tibial guide between the lateral femoral condyle and the PCL. When the tip impinged against these structures, a wallplasty was performed. A *wallplasty* is defined as the incremental removal of bone from the medial aspect of the lateral femoral condyle until the space between the lateral wall and the PCL is as wide as the diameter of the ACL graft (Figure 2). In the cases requiring a wallplasty, the notch was widened with an angled osteotome. The width of the wallplasty was estimated within 1 mm by placing a 2-mm-wide probe as a reference along the edge of the excised bone. The location and extent of the wallplasty were photographed. The tip of the guide was inserted between the PCL and the lateral femoral condyle. The knee was extended and the heel was placed on a Mayo stand. The height of the Mayo stand was adjusted to position the knee in maximum extension.

The handle of the guide was grasped with the long and middle fingers (Figure 3). The handle was rotated anteriorly and superiorly until the tip of the guide abutted against the tibia and the bump of the guide abutted against the intercondylar roof. During rotation of the guide, the hypothenar area of the hand gently pushed the patella posteriorly against the femur to maintain the knee in maximum extension. From the lateral side of the guide, an alignment rod was inserted into the proximal hole in the handle. The guide was rotated until the alignment rod was parallel to the joint line of the tibia and perpendicular to the long axis of the tibia. Alignment of the rod using these 2 reference points placed the tibial tunnel at 65° with respect to the medial joint line in the coronal plane.[16] The drill sleeve was inserted into the tibial guide, gently pressed against the tibia, and locked in the guide. A 2.4-mm drill-tipped guidepin was drilled through the tibia.

Criteria for an Acceptable Lateral Radiograph

To reduce the number of repeat radiographs and radiation exposure, a lateral radiograph with an offset of the femoral condyles of 6 mm or less was accepted in our study. The justification for accepting a 6-mm offset of the femoral

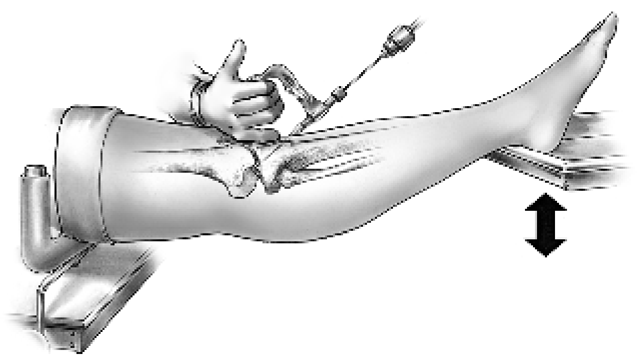

Figure 1. The patient, who was under a general anesthetic, was placed in a supine position on the operating table. A tourniquet was applied to the thigh, and the thigh was clamped in a leg holder. The heel was placed on a Mayo stand, and the height was adjusted until the knee was extended.

Figure 2. The tip of the tibial guide that targets the intercondylar roof is 9.5 mm wide. When the tip impinged against the lateral femoral condyle and PCL, the notch was widened (black line) using an angled osteotome. The thickness of the wallplasty ranged from 0 to 4 mm. The guide wire was drilled after completing the wallplasty. A roofplasty was not performed on any knee.

condyles was based on the calculation of the imprecision (precision) from a pilot study involving 4 subjects. The treated knee was positioned in full extension, a sterile quarter (25 cents in US currency) was taped to the skin for magnification correction using the technique described by Conn et al,[5] and permanent images were obtained with an image intensifier with the femoral condyles in 3 positions: (1) superimposed, (2) internal rotation with a 6-mm offset, and (3) external rotation with a 6-mm offset (Figure 4). *Imprecision* was defined using ASTM standards (www.astm.org) as the standard deviation of the difference in the tibial position on the femur between the rotated and superimposed views.[2] The imprecision caused by a 6-mm offset of the femoral condyles was 0.5 mm.

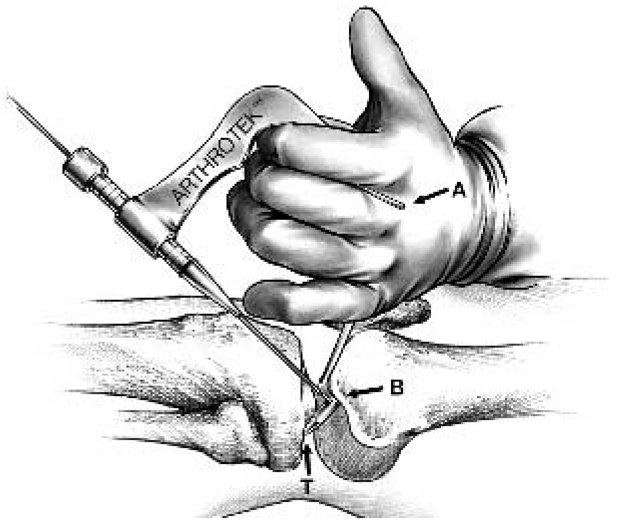

Figure 3. Correct positioning of the tibial guide (65 Degree Howell Tibial Guide) that targets the intercondylar roof, with the heel on a surgical stand and the knee in maximum extension. The index and long fingers rotate the guide anteriorly and superiorly, abutting the tip of the guide (T) against the tibia and the bump (B) of the guide against the intercondylar roof. The hypothenar area pushes the patella and femur posteriorly, the drill sleeve pushes the tibia posteriorly, and gravity pulls both the femur and tibia posteriorly. The guide was rotated until the alignment rod (A) was parallel to the tibial joint line and perpendicular to the long axis of the tibia, which placed the angle of the tibial tunnel in the coronal plane at 65°.

Radiograph of Extended ACL-Deficient Knee With and Without the Tibial Guide

In 14 subjects with torn ACLs, the tibial guidepin was drilled. A quarter was centered over the lateral femoral condyle. A lateral image of the knee was obtained using an image intensifier. In 8 of these subjects, the knee was flexed, the guide was removed, and the heel was replaced on the Mayo stand. Without changing the position of the leg, the lateral image was repeated with the tibial guide removed (Figure 5).

Radiograph of Extended Normal Knee in a Single-Leg Stance

Fourteen subjects with tears of the ACL and contralateral normal knees were enrolled in the study. Subjects with tears of the PCL, MCL, or lateral collateral ligament that required operative repair were excluded. To determine the position of the tibia relative to the femur in the sagittal plane, a preoperative lateral radiograph was obtained of the contralateral normal knee in extension in a single-leg stance (Figure 6).[1] A quarter was centered over the lateral femoral condyle and taped to the skin. The subject stood with the knee in extension in a single-leg stance, with the lateral side of the knee facing the x-ray source of a floor-mounted fluoroscope. Fluoroscopy was activated, and the knee was maneuvered until the medial and lateral femoral condyles and the medial and lateral tibial joint lines were superimposed. The radiograph was exposed.

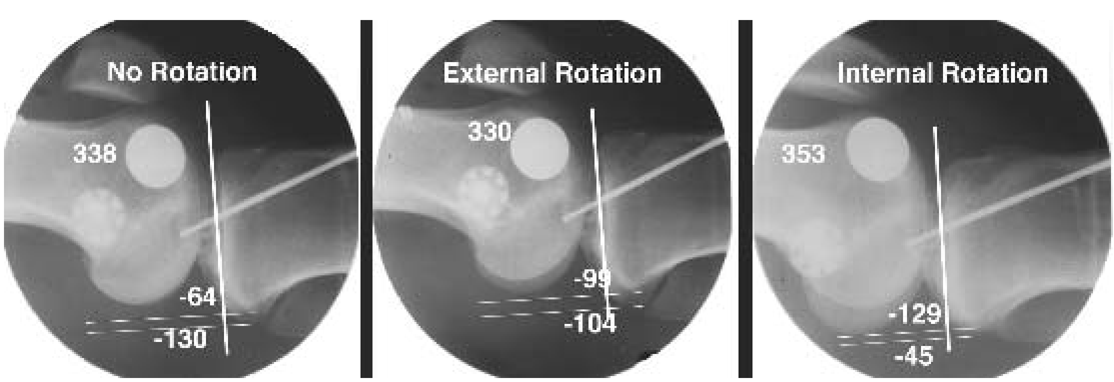

Figure 4. An image intensifier view of the knee with the femoral condyles superimposed, internally rotated with a 6-mm offset, and externally rotated with a 6-mm offset. The imprecision caused by a 6-mm offset of the femoral condyles was 0.5 mm. The quarter placed on the skin (white oval) was used to correct the position of the tibia on the femur for magnification. Using a previously described technique, the position of the tibia was measured with respect to the medial and lateral femoral condyles on each radiograph (see Materials and Methods section).[1,6]

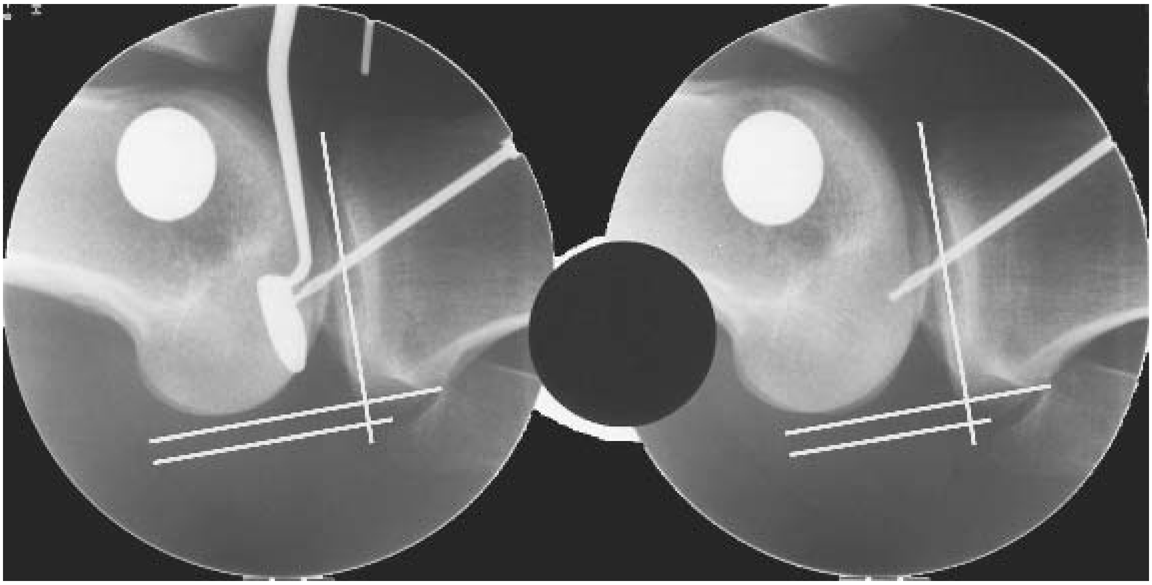

Figure 5. An image intensifier view of the knee with (left) and without (right) the tibial guide. The average difference in the position of the tibia with and without the guide was 0.1 ± 0.2 mm, which indicates that position of the tibia relative to the femur was determined by gravity and not by the tibial guide.

Drilling the Tibial Tunnel and Assessing Roof Impingement

The tibial tunnel was drilled with a cannulated reamer that matched the diameter of the double-looped semitendinosus-gracilis graft. The portion of the ACL insertion overhanging the entrance of the tibial tunnel was excised with a shaver. The heel was replaced on the Mayo stand to restore extension. An impingement rod (Arthrotek Inc), 1 mm smaller in diameter than the tunnel, was passed through the tibial tunnel and into the intercondylar notch. Free passage indicated the absence of roof impingement. With the knee in extension, the clearance between the anterior surface of the impingement rod and the intercondylar roof was estimated with a nerve hook with a 1.5-mm-diameter tip.

Calculation of Tibial Position From a Lateral Radiograph

To obtain a digital image, each radiograph was scanned with a transparency unit at 600 dots per inch and 8 bits grayscale depth (Epson Expression 636, Epson America Inc, Torrance, Calif). The zoom-in tool magnified the area of interest (Adobe Photoshop, Adobe Inc, San Jose, Calif) until it filled the screen of a 22-inch monitor (Apple Cinema Display, Apple Computer Inc, Cupertino, Calif). Distance was measured in pixels using the ruler tool.

The degree of magnification was determined for each radiograph by calculating a magnification factor. On each image, the maximum diameter of the quarter placed on the skin was measured in pixels. The magnification factor was the actual diameter of the quarter in millimeters (24.18 mm) divided by the maximum diameter of the quarter in pixels.

Figure 6. A lateral radiograph was taken of the knee with the subject bearing weight on the extended knee. The leg was positioned under fluoroscopy until the medial and lateral femoral condyles and the medial and lateral tibial joint lines were superimposed. To correct for magnification, a quarter was taped to the skin on the lateral side of the knee, centered over the femoral condyle and facing the source of the x-ray beam. The foot of the leg not being imaged was lifted off the platform.

Using a previously described technique,[1,6] the position of the tibia was measured with respect to the medial and lateral femoral condyles on each radiograph. The precision of the radiographic measurement has been reported to be 0.05 ± 0.03 mm.[6] A line was drawn along the subchondral plate of the tibial plateau. Additional lines were drawn tangential and parallel to the most posterior extent of the medial and lateral tibial plateau and perpendicular to the first line (Figure 4). The posterior extent of each tibial plateau was easily distinguished from one another because the posterior margin of the lateral tibial plateau is narrow and pointed, and its outline is continuous with the lateral tibial eminence. The posterior medial tibial plateau is the larger and squarer of the two, and the posterior surface is flat. The shortest distance from each line to the most posterior extent of the medial and lateral femoral condyles was measured. The lateral femoral condyle is easily distinguished from the medial femoral condyle because it is larger and has a higher anterior trochlear ridge, as well as an indentation in its distal articular surface (condylar sulcus). The medial femoral condyle has no sulcus, is smaller, and has a lower anterior trochlear ridge. A positive value was recorded when the offset of the posterior margin of the tibia was anterior to that of the femoral condyle. A negative value was recorded when the offset of the posterior margin of the tibia was posterior to that of the femoral condyle. The positions of the medial and lateral hemijoints of the tibia in millimeters were each calculated by multiplying the offset in pixels by the magnification factor. The tibial position in millimeters was the average of the position of the medial and lateral hemijoints.

Calculation of Knee Extension, Roof Angle, and Tibial Guidepin Position

Knee extension, roof angle, and the distance from the center of the tibial guidepin to the intercondylar roof were determined from the lateral radiograph obtained of the treated knee in maximum extension (Figure 7). Knee extension was the angle subtended by a line drawn along the longitudinal axis of the femur and tibia. Roof angle was the angle subtended by a line drawn along the longitudinal axis of the femur and the intercondylar roof. Measuring the distance from the center of the guidepin to the intercondylar roof in pixels and multiplying by the magnification factor calculated the distance in millimeters from the center of the guidepin to the intercondylar roof.

STATISTICAL ANALYSIS

Using the Student paired t test, comparisons of the position of the tibia between the treated knee with the tibial guide in position and the contralateral normal knee in a single-leg stance were made were made in 14 subjects, and comparisons were made between the knee with and without the guide in 5 subjects. Significance was set at $P < .05$.

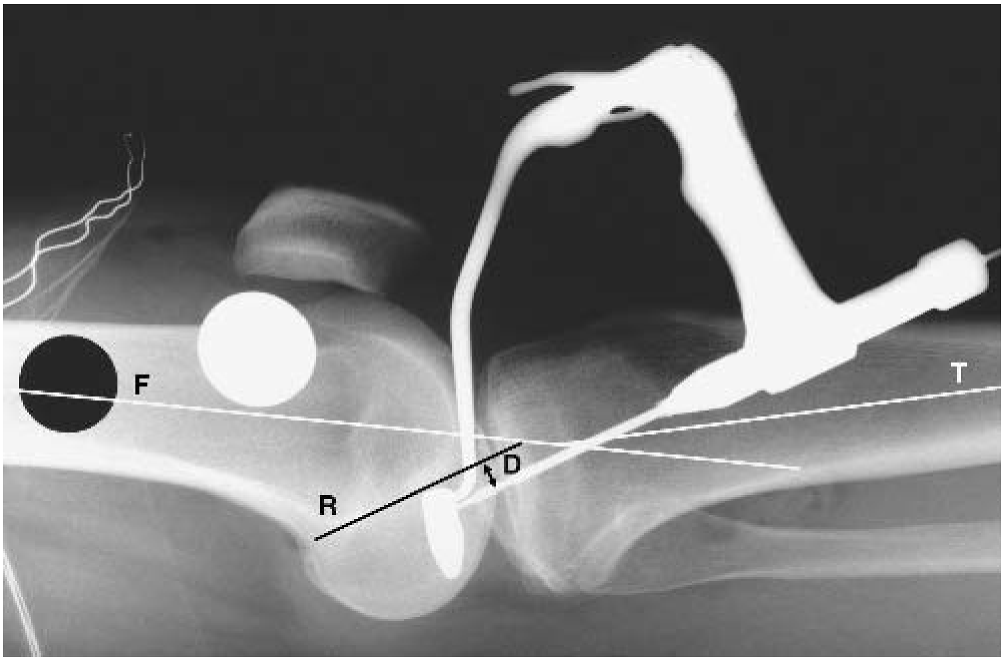

Figure 7. Radiograph of tibial guide that targets the intercondylar roof and guidepin in position with the knee in passive hyperextension. Knee extension was the angle subtended by a line drawn along the longitudinal axis of the femur (F) and tibia (T). Roof angle was the angle subtended by a line drawn along the longitudinal axis of the femur (F) and the intercondylar roof (R). Placement was the distance between the center of the guidepin and the intercondylar roof (D). A guidepin placed 6.5 ± 0.5 mm posterior and parallel to the intercondylar roof with the knee in maximum extension is correctly positioned.

RESULTS

Fourteen subjects (11 male, 3 female) with a mean age of 33 ± 12 years (range, 17-49 years) participated in the study. The time interval from injury to surgery averaged 43 ± 89 months (range, 1.5-246 months).

Operative Treatment

Eight of 14 knees had one or more meniscal tears. One knee had a locked bucket-handle tear of the medial meniscus, and one had a locked bucket-handle tear of the lateral meniscus, both of which were repaired. There were 5 other medial meniscal tears: 1 was repaired, 3 were excised, and 1 was previously excised. There were 2 other lateral meniscal tears: 1 was excised and 1 was previously excised. One patient initially had a grade 3 and one patient had a grade 2 MCL laxity, both of which had partially healed during the several weeks required to regain motion in the knee before surgery. No patients had laxity of the lateral collateral ligament.

An 8-mm-diameter tibial tunnel was drilled in half the knees, and a 9-mm-diameter tunnel was drilled in the others. The size of the tunnels was determined by the diameter of the double-looped semitendinosus-gracilis autograft. The wallplasty was performed until the space between the PCL and the lateral femoral condyle was greater than the diameter of an 8- or 9-mm-diameter graft. Thirteen of 14 knees required a wallplasty to insert the 9.5-mm-wide tip of the tibial guide into the notch without impingement against the lateral femoral condyle and PCL. In 6 knees, the wallplasty was only required in the superior half of the notch because the inferior half of the notch was at least as wide as the graft diameter. The extent of wallplasty ranged from 2 to 4 mm. With the knee in maximum extension, the clearance between the impingement rod and the intercondylar roof was judged with a 1.5-mm-thick nerve hook probe and was 2 mm or less.

Position of the Tibia Is Not Determined by the Guide

The position of the tibia with the guide (–2.2 ± 3.0 mm) was not different from the position of the tibia without the guide (–2.1 ± 3.0 mm; *P* = .33, not significant). The use of the guide did not change the position of the tibia.

Analysis of Tibial Position

The intraoperative position of the tibia (–2.2 ± 1.3 mm) in the knee with a torn ACL was 0.7 mm more posterior than the contralateral normal knee in extension in a single-leg stance (–1.5 ± 1.0 mm; *P* = .0075; Table 1).

Analysis of Knee Extension, Roof Angle, and Tibial Guidepin Position

Mean knee extension was 7° ± 5° of hyperextension, with a range from –18° of hyperextension to 0°. Mean roof angle was 34° ± 5°, with a range from 27° to 40°. The distance from the center of the tibial guidepin to the intercondylar roof was 6.5 ± 0.5 mm, with a range from 5.6 to 7.6 mm. The 6.5-mm distance from the center of the tibial guidepin to the intercondylar roof translates into a clearance of 2.5 mm for an 8-mm-diameter ACL graft, 2.0 mm for a 9-mm-diameter ACL graft, and 1.5 mm for a 10-mm-diameter ACL graft.

DISCUSSION

One important observation of our study is that gravity reduced the tibia, as the tibial position was virtually unchanged on the radiograph of the knee, suspended in full extension, with and without the guide. Another important observation was that the use of a tibial guide that targets the intercondylar roof prevents roof impingement without positioning the tibial tunnel too posteriorly and without a roofplasty. These observations apply to a knee with a torn ACL with one or more tears of the menisci and the knee with a torn MCL that does not require repair.[16] Before discussing the clinical implications of these observations, method issues and a limitation of the study should be examined.

Method Issues and Limitations

One method issue was that to determine whether the tibial guide reduced the tibia in the knee with the torn ACL, the contralateral normal knee in extension in a single-leg stance was used as the control instead of the knee in passive extension during the operation. The contralateral knee in a single-leg stance was used because contraction of the quadriceps translates the tibia anteriorly, which can cause dynamic roof impingement.[8,9] The avoidance of dynamic roof impingement during activities of daily living and rehabilitation exercises depends on placement of the tibial tunnel, with the tibia positioned as it is during contraction of the quadriceps. In the present study, the position of the tibia of the contralateral normal knee in extension in a single-leg stance was within 0.7 mm of the position of the tibia during use of the tibial guide that references the intercondylar roof. The difference of 0.7 mm is within the reported measurement difference of 2.5 mm between 2 normal knees[6] and is clinically insignificant. Therefore, the use of the normal knee in a single-leg stance as the control suggests that the use of the tibial guide that references the intercondylar roof minimizes dynamic roof impingement during activities of daily living and rehabilitation exercises.

A second method issue was the use of image analysis and a quarter to calculate a magnification ratio for each radiograph. Acquiring a digital image of the radiograph at 600 dots per inch and using the zoom-in tool to magnify the region of interest allowed distances to be measured with an accuracy of 1 pixel, or 0.04 mm. Obtaining a radiograph of the knee with a quarter placed on the skin and scanning the radiograph to form a digital image provided a method to calculate an accurate magnification ratio.[5] Although the magnification was substantially higher in the preoperative

TABLE 1
Positions of the Medial and Lateral Tibial Plateau[a]

Subject	Normal Knee Standing			ACL-Deficient Knee With Guide		
	Medial Tibia	Lateral Tibia	Tibia	Medial Tibia	Lateral Tibia	Tibia
1	–5.3	1.2	–2.1	–1.9	–2.0	–2.0
2	–1.3	–3.2	–2.3	–3.8	–1.4	–2.6
3	–1.1	–1.6	–1.3	–1.6	–0.3	–1.0
4	–0.6	–1.6	–1.1	–2.3	–2.9	–2.6
5	–2.8	0.8	–1.0	–3.0	1.2	–0.9
6	–4.4	–2.2	–3.3	–0.8	–5.3	–3.1
7	–1.7	0.8	–0.4	–3.7	0.7	–1.5
8	–1.7	–3.8	–2.7	–2.3	–5.1	–3.7
9	–1.2	–0.6	–0.9	–2.0	–1.8	–1.9
10	–2.4	2.1	–0.2	0.0	–0.5	–0.3
11	–1.7	0.5	–0.6	–5.7	0.2	–2.8
12	–2.3	–4.1	–3.2	–6.3	–4.1	–5.2
13	–0.6	–0.4	–0.5	0.9	–3.0	–1.0
14	–4.6	1.2	–1.7	–4.2	–0.3	–2.2

[a]Positions of the medial and lateral tibias (in millimeters) with respect to the femur in the normal contralateral knee with the patient standing in a single-leg stance and in the treated knee intraoperatively after drilling the tibial guidepin in the 14 subjects.

radiographs (63%) than in the intraoperative radiographs (25%), the use of a quarter allowed correction for magnification and an accurate calculation in millimeters of the position of the tibia relative to the femur.

A limitation of our study is that we did not evaluate the tibial position in a knee that required an open repair of a torn lateral collateral ligament, a torn posteromedial or posterolateral capsule, or a torn PCL. These multiligament injuries, which constitute 1 of 150 ACL reconstructions in our practice, may have the potential to affect the reduction of the tibia with the knee in maximum extension. When we perform an ACL reconstruction in the rare knee with a multiligament injury that requires an open repair, we first obtain an intraoperative lateral radiograph of the knee in full extension with the guidepin in place. If the tibia appears to be more posterior than on a preoperative radiograph of the contralateral normal knee, then the amount of posterior translation is measured. The guidepin is moved the same distance posteriorly with use of a hole changer.

Interpretation of Results

Anatomical placement of the graft requires positioning of the tibial tunnel within the boundary of the normal ACL. The anterior boundary of the normal ACL with the knee in maximum extension grazes and is parallel to the slope of the intercondylar roof.[12,14,23] The insertion boundary of the normal ACL is greater than the body of the normal ACL and the graft. The insertion boundary of the normal ACL is broad and averages 19 mm in the sagittal plane, which is nearly twice the 10-mm width of the more proximal portion body of the normal ACL.[7,14] The smaller grafts made from soft tissue (cylindrical in cross section) and bone–patellar tendon–bone (rectangular in cross section) cannot replicate the broad insertion of the normal ACL. Centering the tibial tunnel in the posterior half of the normal ACL insertion places the graft in an anatomical position within the anterior boundary of the normal ACL and eliminates the need for a roofplasty.[14] Centering the tibial tunnel in the anterior half of the normal ACL insertion places the graft in a nonanatomical position and anterior to the anterior boundary of the normal ACL, and an extensive roofplasty is required to prevent roof impingement.[17,24]

The tibial guide that targets the intercondylar roof with the knee in maximum extension centers the ACL graft in the posterior half of the ACL insertion by customizing the sagittal position of the graft for wide variability in roof angle and knee extension between knees.[11,12] Customizing the placement of the tibial tunnel is necessary to avoid a roofplasty because, based on the results of prior studies, roof angle varies from 23° to 60° and knee extension varies from –20° to 5°.[4,12] In the present study, the variability in roof angle (27° to 40°) and knee extension (–18° to 0°) was similar to the variability in angles found in these previous studies. By targeting the intercondylar roof with the tibial guide and drilling the guidepin with the knee in maximum extension, the wide variability in roof angle and knee extension was accounted for simultaneously.[12]

The tibial guide also prevents roof impingement without placing the tibial tunnel too posteriorly and without performing a roofplasty. To assess the position of the tibial tunnel arthroscopically with respect to the intercondylar roof, an impingement rod and nerve hook probe were used. The knee was placed in maximum extension, and the impingement rod was inserted into the notch through the tibial tunnel. In each knee, the impingement rod passed freely without obstruction, confirming that the tibial tunnel was placed without roof impingement. A 1.5-mm-wide nerve hook was inserted and manipulated between the anterior surface of the impingement rod and the intercondylar roof with the knee in maximum extension. In each knee, the clearance between the rod and roof was judged to be 2 mm or less. The position of the tibial tunnel with respect to the intercondylar roof was radiographically assessed by the measurement of the clearance between the guidepin and intercondylar roof on the lateral radiograph. The clearance was 1.5 mm for a 10-mm-diameter ACL graft, 2.0 mm for a 9-mm-diameter ACL graft, and 2.5 mm for an 8-mm-diameter ACL graft. The arthroscopic assessment and the radiographic measurement were in agreement that the tibial guide that references the intercondylar roof with the knee in full extension prevents roof impingement, without placing the tibial tunnel too posteriorly and without a roofplasty. The avoidance of a roofplasty benefits knee function, surgery, and blood loss by decreasing anterior translation,[8] operative time, and intra-articular bleeding.

Correct placement of the tibial tunnel with use of a tibial guide that targets the intercondylar roof depends on the tibia being reduced.[1] The present study showed that gravity reduces the tibia when the patient is supine, an anesthetic is administered, and the leg is suspended with the knee in maximum extension (Figure 1). Administering an anesthetic eliminates anterior tibial translation from a quadriceps contraction. Suspending the leg with the knee in maximum extension by placing the heel on an adjustable Mayo stand prevents unwanted anterior displacement of the tibia that might result from resting the leg on a bump or holding the leg by hand. Because the tibia is reduced when using a tibial guide that targets the intercondylar roof, surgeons can be confident that the tibial tunnel will not be placed too anteriorly or posteriorly.

The gravitational reduction of the tibia relieves the surgeon from the technical concern that skillful manipulation of the guide is required to reduce the tibia. The benefit of not needing to manipulate the guide to reduce the tibia might provide a more consistent, customized placement of the tibial tunnel. A multicenter study involving 5 surgeons evaluated the consistency of the tibial guide that targets the intercondylar roof. The 5 surgeons placed the tibial tunnel without roof impingement and without placing the tibial tunnel too posteriorly in 119 of 119 knees.[16]

The surgeon who uses a PCL-referencing or point-and-shoot guide and positions the tibial guidepin in the same location in every knee may find it initially troubling to assess the correctness of the guidepin placed with a tibial guide that targets the intercondylar roof. Trouble in assessing the correctness of the position of the guidepin may arise because the tibial guide that targets the intercondylar roof intentionally varies the location of the guidepin. Variability in the location of the guidepin between patients occurs because roof angle varies 37° and knee extension varies 25°.[4,12] A lateral intraoperative radiograph of the knee in maximum extension is useful in determining whether the placement of the guidepin is correct. A guidepin placed 6.5 ± 0.5 mm posterior and parallel to the intercondylar roof with the knee in maximum extension is correctly positioned (Figure 7). It has been our experience that a new user acquires confidence with the guide, so that the intraoperative lateral radiograph can be dispensed with after 3 to 5 cases.

Although posterior placement of the tibial tunnel with a guide that targets the intercondylar roof has not been reported, it has been reported with a guide that references the PCL. Miller and Olszewski showed that a PCL-referencing guide with a 7-mm offset creates an average clearance of 8.3 mm between an impingement rod and the intercondylar roof with the knee in maximum extension.[20] The 8.3-mm clearance is excessive because in the normal knee there is little to no clearance between the intact ACL and the intercondylar roof with the knee in maximum extension.[14] Hutchinson and Bae recommended increasing the offset on the PCL-referencing guide from 7 to 10 or 11 mm to reduce the excessive clearance and prevent the guide from placing the tibial tunnel too posteriorly.[18]

Although anterior placement of the tibial tunnel with a guide that targets the intercondylar roof has not been reported, it has been reported with a point-and-shoot guide that references the insertion of the ACL. In our hands, the use of a point-and-shoot guide resulted in anterior placement of the tibial tunnel and roof impingement.[10,13,15,17] The cause of the anterior placement is the broad 19-mm insertion of the ACL, which lulls the surgeon into centering the tibial tunnel in the anterior half of the insertion, which places the tibial tunnel too anteriorly.[14]

A customized wallplasty of 2 to 4 mm was performed in 13 of 14 knees to create enough space between the PCL and the lateral femoral condyle so that impingement of the graft against the PCL and lateral femoral condyle was minimized. The wallplasty was performed until the space between the PCL and lateral femoral condyle was greater than the diameter of an 8- or 9-mm-diameter graft. In 6 knees, the wallplasty was confined to just the superior half of the notch because the inferior half of the notch was at least as wide as the graft diameter. To our knowledge, there are no reports of adverse effects from a customized wallplasty limited to 2 to 4 mm. A small wallplasty that widens the notch for a 9-mm graft is compatible with a tension pattern in the graft that replicates the tension of the intact ACL.[22] In contrast to a small wallplasty, a roofplasty and a roofplasty in combination with a wallplasty have been reported to increase anterior translation,[8] increase mean intra-articular pretension in the graft required to restore normal anteroposterior laxity, and increase anterior laxity.[19]

Presumably, a nerve hook probe could be used with any type of tibial guide (ie, point and shoot, PCL referencing, intercondylar roof) to verify the clearance of the guidepin from the intercondylar roof before drilling the tibial tunnel. However, our study did not determine whether the nerve hook is useful in assessing the position of the guidepin before drilling the tibial tunnel. In our study, the nerve hook probe was used to assess clearance after drilling the tibial tunnel, which does not allow the position of the tibial tunnel to be changed if the clearance is found to be too little or too great. The use of a nerve hook to judge the sagittal position of the guidepin placed by a guide that targets the intercondylar roof, a PCL-referencing guide, and a point-and-shoot guide requires further study.

In summary, the use of a tibial guide that targets the intercondylar roof with the knee in full extension prevents roof impingement without a roofplasty and without positioning the tibial tunnel too posteriorly. Gravity reduces the tibia on the femur when the knee is suspended in extension. The guide is effective in the knee with a torn ACL that may also have one or more tears of the menisci and a tear of the MCL that does not require operative repair. We did not study the effectiveness of the guide in a knee with a torn PCL or a knee that requires an open repair of a collateral ligament; however, we do use the guide in these cases, and when there is any uncertainty, we check the position of the guidepin using a radiographic control.

ACKNOWLEDGMENT

We are indebted to the technicians and the Radiology Department at Methodist Hospital, Sacramento, California, for obtaining the images in this study.

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