Anatomic Single-Bundle Anterior Cruciate Ligament Reconstruction From the Anteromedial Portal: Evaluation of Transverse Femoral Fixation in a Cadaveric Model

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Purpose: The purpose of this study was to assess the risk of injury to the posterolateral structures of the knee when performing anterior cruciate ligament reconstruction from the anteromedial portal while fixing the graft with a femoral cross-pin system. **Methods:** The anterior cruciate ligament was reconstructed arthroscopically with hamstring graft in 10 fresh cadaveric knees. Femoral fixation was performed with a cross-pin system. This was originally developed for a transtibial drilling technique. A femoral tunnel measuring 30 mm in length was drilled through the anteromedial portal in each knee. The knee flexion angle was set at 110°. Lateral dissection was then performed to measure the distances from the cross-pin system to the lateral collateral ligament, the popliteus tendon, the lateral gastrocnemius tendon, and the peroneal nerve. **Results:** The lateral collateral ligament was partially torn by the pin in 1 case. In 8 cases the distance to the lateral collateral ligament was shorter than 3 mm (range, 0 to 2.43 mm). In 7 specimens, the cross-pin system was within 4.5 mm of the popliteus tendon. The lateral gastrocnemius tendon was pierced by the cross-pin device in 2 cases. The minimal distance to the peroneal nerve was 23.89 mm. **Conclusions:** Fixation of a hamstring graft with a cross-pin system initially developed for an upper femoral tunnel, following the aforementioned technique, presents the possibility of a high risk of injury to the lateral collateral ligament. The popliteus tendon and the lateral gastrocnemius tendon may also be injured. **Clinical Relevance:** The risk of injury to the lateral stabilizers of the knee suggests discarding the technique used in this study.

The main function of the anterior cruciate ligament (ACL) has been accepted as being the principal restraint against anterior tibial displacement for years. More recently, the important role of the ACL in rotatory stability of the knee has been put forth.[1-3] It acts against combined rotatory loading of internal tibial and valgus torques. Consequently, the way surgeons reconstruct the ACL has changed according to new findings. For several years, performing femoral tunnel placement in the so-called over-the-top position was considered standard for ACL reconstruction.[4,5] Furthermore, anatomic studies[6-8] and biomechanical studies[2,9,10] have recently suggested that this might be an improvement over other femoral tunnel placements. Lowering the femoral tunnel from the 11-o'clock position to the 10-o'clock position has been shown to provide better control of the aforementioned rotatory instability.[2,9,10]

There are 2 major techniques for creating the femoral tunnel. One is drilling through the tibial tunnel (transtibial technique [TTT]), and the other is drilling through the anteromedial portal (anteromedial portal technique). Attempts to place the graft at the original

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anatomic insertion site with a TTT show that this is not easily done.[11,12] It requires drilling the tibial tunnel from a more medial starting point. However, there is a risk of damage to the medial plateau cartilage because of the obliquity of the tunnel and of partial injury to the medial collateral ligament if the aforementioned approach is taken. The other solution would be to drill the femoral tunnel through a low anteromedial portal.[12,13]

Hamstring tendons have provided good results as a graft option for ACL reconstruction.[14] They can be secured proximally with different fixation techniques. One of these, the transverse femoral fixation system, was originally developed for drilling the femoral tunnel transtibially.[15] The transverse pins are placed percutaneously through the lateral femoral condyle, and this technique has been shown not to damage the surrounding anatomic structures[16] when femoral tunnel placement is performed in the high over-the-top position. Nevertheless, lowering the femoral tunnel could involve a risk of iatrogenic lesions to the posterolateral structures of the knee when drilling through the transverse guide. Pujol et al.[17] compared placement of the femoral tunnel transtibially with placement through the anteromedial portal at different flexion angles. They concluded that the anteromedial portal technique presents no risk when the knee is flexed at least 130°. However, they did not specify the exact position of the starting femoral point. Furthermore, they used the same femoral starting drilling point for both the TTT and the anteromedial portal technique. Therefore it can be hypothesized that the femoral tunnel was not placed in the anatomic position with either technique.

The aim of this study was to evaluate the risk of iatrogenic lesions when performing strict low femoral tunnel positioning from the anteromedial portal. The hypothesis is that when using the recommendations for tunnel length of the Cross-Pin technique (Stryker, Kalamazoo, MI), which was described for the TTT, the posterolateral structures could be put at risk.

METHODS

We studied 11 whole lower-extremity fresh-tissue knees (6 left and 5 right) from adult human volunteer donors. Seven were from male donors and four from female donors. None of the knees showed macroscopic signs of previous surgery. One knee that showed a remarkable narrowing of the intercondylar notch during arthroscopic examination was excluded from the study. The remaining 10 specimens ranged in age from 68 to 96 years (mean, 83.5 years). They were mounted on a knee holder (Extremity Holder; Sawbones, Malmö, Sweden).

By use of a long metal ruler, the longitudinal axis of the thigh, defined as the line passing through the greater trochanter and the lateral epicondyle, was marked with a skin pen. The longitudinal axis of the leg passing through the center of the fibular head and the lateral malleolus was also marked. A manual goniometer was used to measure the angle between the 2 lines so that the femorotibial flexion could be calculated.

The gracilis and semitendinosus tendons were harvested through a 30-mm longitudinal approach medial to the tibial tuberosity. A whipstitch suture was performed on each end of the tendons. A 0.8-mm copper wire was also included so that the sutures would be more easily recognized on later radiographic imaging. The diameter of the double-loop hamstring graft structure was then measured.

The experimental protocol was as follows: first, the ACL reconstruction was performed, and the transverse fixation was implanted. Second, a radiographic evaluation of the femoral tunnel position was done. Finally, dissection of the lateral aspect of the knee was performed, and the relation of the Cross-Pin device to the surrounding structures was evaluated.

Arthroscopic Procedure

All arthroscopic procedures were performed by the same author. The knees hung freely at 90° of flexion except when the femoral tunnels were being drilled. A standard anterolateral portal was established as the viewing portal. A low anteromedial portal was then established as the working portal. The landmarks used to establish this portal were the inferior pole of the patella and a point 1 cm medial to the patellar tendon.

After complete excision of the ACL, the lateral wall of the intercondylar notch was cleared by use of a shaver. The tibial tunnel position was marked at the center of the ACL stump. Depending on the diameter of the hamstring graft, a 7- to 10-mm hole was made with a conventional step drill guide (ACL System; Stryker).

The starting point was always located 2 cm medial to the tibial tuberosity. The inclination angle on the sagittal plane was set at 55°. The deviation from the axis perpendicular to the tibial plateau in the frontal plane was 20°. Subsequently, the femoral tunnel was placed with a measured knee flexion of 110°. The corresponding offset femoral tunnel guide was se-

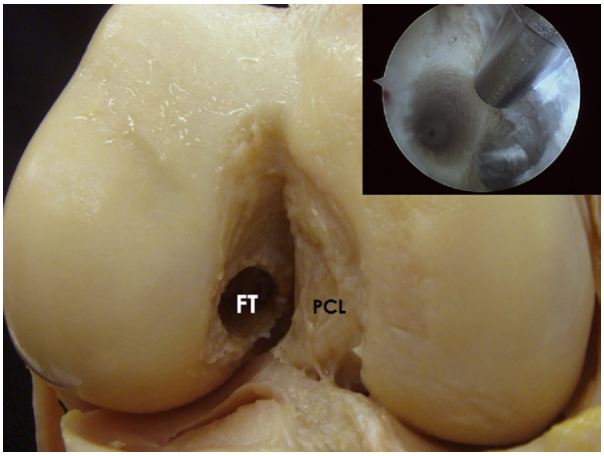

FIGURE 1. Anterior view of right knee. The femoral tunnel was drilled at the anatomic insertion point of the ACL. Inset, arthroscopic picture of same knee showing that only 1 to 2 mm of posterior wall was left behind the tunnel. (FT, femoral tunnel; PCL, posterior cruciate ligament.)

lected to leave 2 mm of posterior wall to approach the appropriate anatomic deep/shallow position[18] and to avoid blowout. The clock-face position was carefully established at the 10-o'clock position (right knee) or 2-o'clock position (left knee) with reference to the inside of the notch (Fig 1). This is known to be the intermediate point between the anteromedial and posterolateral bundles at the high/low position.[19] Following the recommendation for the Cross-Pin technique (Stryker), the femoral tunnel was drilled over the guide pin to a depth of 30 mm whenever possible. The transverse drill guide was then introduced into the femoral socket, and a pin was drilled percutaneously into the lateral aspect of the knee, 20° upward with reference to the horizontal plane. The hamstring graft was then introduced and fixed on the femoral side with either a 6 × 40– or 6 × 50–mm Biosteon (hydroxyapatite/poly-L-lactic acid) Cross-Pin (bCP) (Stryker). Tibial fixation was performed with a 7 × 25–mm or 10 × 25–mm standard metal screw.

Radiographic Evaluation

A tunnel-view radiograph was obtained for each specimen at 30° of knee flexion. In accordance with a recently described method, the femoral tunnel orientation with reference to a line tangent to the distal aspect of the femoral condyles was measured.[20] A computer software–generated clock face was then superimposed such that 12 o'clock was the highest point of the notch. The entry point of the pins was expressed in hours and in quarter-hour intervals and normalized for each knee.

Dissection and Evaluation of Posterolateral Structures

Dissection was performed through a 20 × 15–cm ovoid-shaped skin incision centered on the lateral femoral condyle. The skin and subcutaneous tissue were excised. Identification of the fascia lata was then done. To easily assess the lateral aspect of the femur, the posterior half of the fascia lata was removed. Localization of the Cross-Pin device and careful dissection of the lateral aspect of the knee were performed to identify the following structures: lateral collateral ligament (LCL), lateral epicondyle, popliteus tendon (PT), lateral gastrocnemius tendon (LGT), and peroneal nerve (PN). After complete excision of the lateral attachments of the knee, distances from the pin to the anterior, posterior, and distal surfaces of the femur were also evaluated.

The shortest distance from the pin to the corresponding structures was then calculated twice by 2 of the authors and then averaged. All measurements were determined by use of an electronic digital caliper (ProMax; Fred V. Fowler, Newton, MA) (range, 0 to 150 mm; resolution, 0.02 mm). Finally, anterior dissection of the knee joint was performed to certify proper placement of the graft (Fig 2).

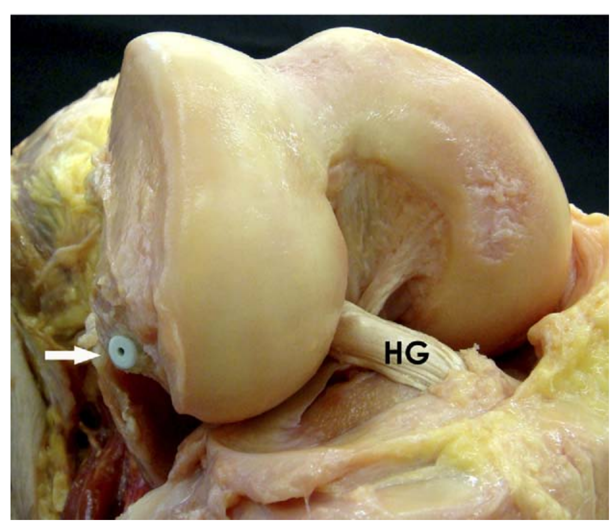

FIGURE 2. Lateral view of right knee, showing Cross-Pin (arrow) inserted into lateral condyle. The hamstring graft (HG) is seen running obliquely from the tibial tunnel, placed in the ACL stump, to the lateral condyle.

RESULTS

In 2 of 10 specimens, the gracilis tendon was discarded because the poor quality of the tissue did not allow for its further manipulation. In 8 cases a 30-mm tunnel depth could be established. In the remaining 2 specimens, only 25- and 23-mm tunnel lengths could be established because of small lateral condyles. In the aforementioned cases, the posterolateral cortex of the femur was perforated. In the latter of the two (case 8), moderate narrowing of the intercondylar notch was observed. Notchplasty was not performed because of our impression that this moderate degree of narrowing would not influence the tunnel placement.

Radiographic Evaluation

The mean angle of the femoral tunnel orientation with reference to the bicondylar line was 52.1° (range, 40° to 60°) (Fig 3). The average clock position was 10 o'clock (range, 9:15 to 10:30).

LCL and Lateral Epicondyle

The position of the bCP with respect to the LCL varied from one specimen to another. In 8 cases the Cross-Pin was placed posterior to the LCL (range, 0 to 7.96 mm; mean, 2.38 mm) (Fig 4). In 1 knee the LCL was partially torn by the bCP (case 9) (Fig 5). Nevertheless, this partial lesion did not produce varus instability under manual testing. In the remaining specimen, the pin was introduced into the femur just anterior to the LCL (case 8). In this specimen the femoral tunnel length was only 23 mm. This anterior deviation might partially be explained by its narrowed intercondylar notch, which could have altered the femoral tunnel guide positioning. In 8 cases the distance to the LCL was shorter than 3 mm (range, 0 to 2.43 mm). The distance from the pin to the lateral epicondyle averaged 13.86 mm (range, 6.41 to 19.04 mm).

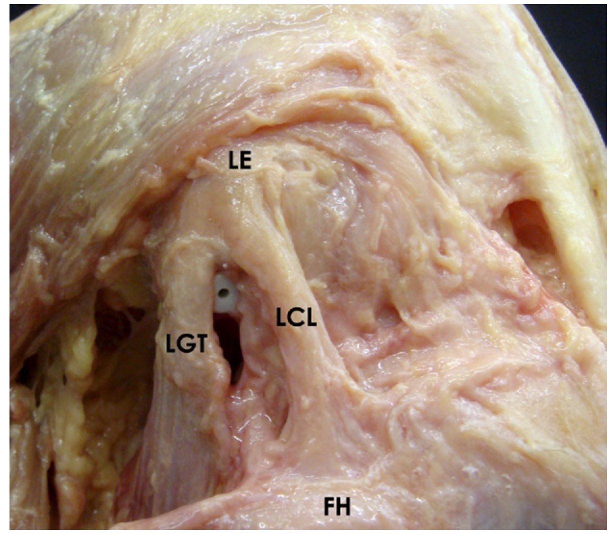

Figure 4. Lateral view of right knee, showing Cross-Pin inserted in lateral condyle. In this case it was placed right in the middle of the LCL and the PT. (LE, lateral epicondyle; FH, fibular head.)

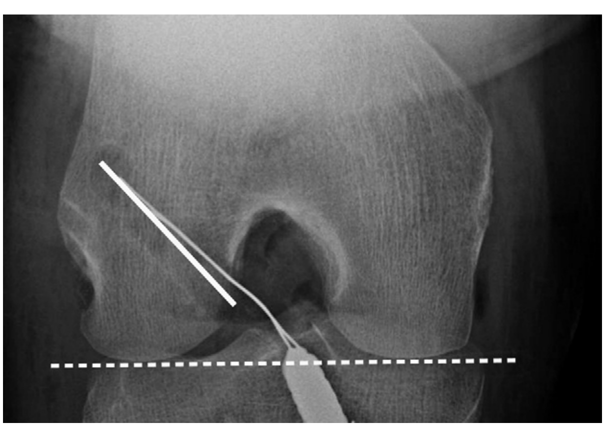

Figure 3. Notch-view radiograph of right knee (case 3). The femoral tunnel orientation (solid line) with reference to a line tangent to the distal aspect of the femoral condyles (dashed line) measured 47°. The center of the femoral tunnel, with respect to the clock-face position, was calculated to be at the 9:45 position.

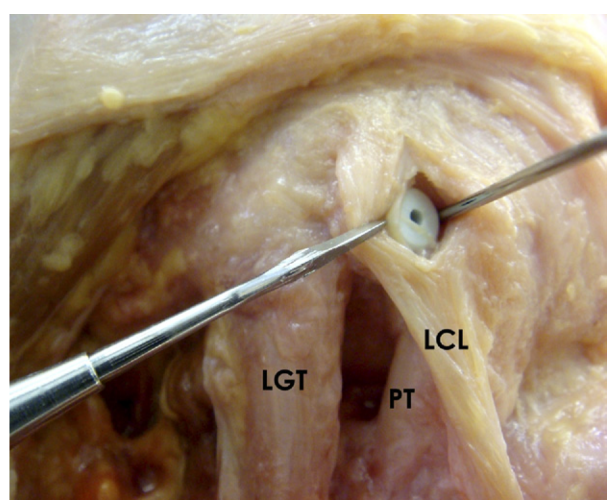

Figure 5. Torn LCL on lateral view of right knee (case 9). Both the anterior and posterior borders of the pierced ligament are retracted to show the pin placement.

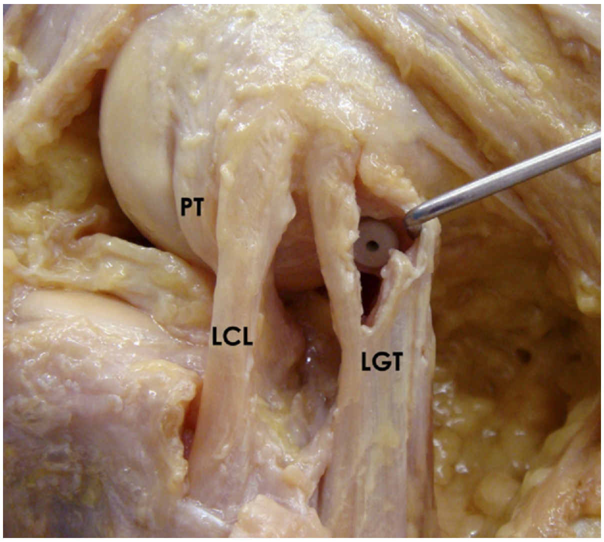

FIGURE 6. Torn LGT due to pin placement on lateral view in left knee (case 7).

Popliteus Tendon

Similarly, the bCP was separated from the PT by as much as 1.47 mm in 3 specimens. The pin was at least 4.5 mm away in only 3 cases.

Lateral Gastrocnemius Tendon

In 2 specimens the LGT was pierced by the bCP (Fig 6). The pin was placed just in contact with the anterior border of the tendon in another 4 cases.

Peroneal Nerve

The minimal distance from the bCP to the PN was 23.89 mm (mean, 38.48 mm).

Femoral Cortices

The mean distance to the anterior surface of the femur was 27.2 mm (range, 17.45 to 35.4 mm). The femur ended distally at a mean of 8.17 mm (range, 4.08 to 15.8 mm). In 1 case the bCP went right into the posterior cortex, with its posterior half facing the popliteal fossa. In 7 cases the Cross-Pin was within 1.52 mm of this posterior surface (mean, 1.35 mm). In the 2 remaining cases, where the pin was placed anteriorly (case 8) or in the middle of the LCL (case 9), the distance to the posterior cortex was 14.06 and 9.5 mm, respectively.

Under direct evaluation of the femoral tunnel, 2 mm of posterior wall was confirmed to be present in every knee. All frequencies are summarized in Table 1.

DISCUSSION

The main finding of this study was that performing femoral tunnel placement at the anatomic insertion site from the anteromedial portal could cause iatrogenic lesions. The LCL is the main structure jeopardized. This is in contrast to the previous work performed by Hantes et al.[21] In their report of more than 30 ACL reconstructions from the anteromedial portal using the Bio-TransFix femoral fixation device (Arthrex, Naples, FL), they concluded that the technique is safe and effective. Nevertheless, they did not evaluate where the cross-pin device was placed with respect to the posterolateral structures. Furthermore, they did not specify the degree of knee flexion or the angulation of the transverse drill with respect to the horizontal plane. Our findings did not match the conclusion of the study by Pujol et al.[17] either. They

TABLE 1. *Distances from Cross-Pin to Corresponding Structures*

Case No.	TL (mm)	LCL (mm)	LE (mm)	PT (mm)	LGT (mm)	PN (mm)	AC (mm)	PC (mm)	DC (mm)	TO (mm)	CFP
1	30	8	18.9	7	0	32.9	31.5	1.8	4.1	50	10
2	30	2.4	12.9	12.6	0	32.3	27.1	0.7	6.3	56	10:15
3	25	0.9	10.9	4.5	5.2	51.9	33.7	0.9	9.2	47	9:45
4	30	2	15	4.4	4.3	30.6	35.4	1.3	6.6	60	10:30
5	30	0	13.6	3.9	0	37.5	24.5	1.8	8.9	53	10
6	30	0	12.4	3.3	0	39.1	24.8	1.5	15.8	50	10
7	30	5.7	19	9.5	0	46.4	30	0	7.2	57	10:15
8	23	0.4	17.2	0	11.9	39.5	21.5	14.1	6.4	44	9:15
9	30	0	6.4	0	3	50.8	17.4	9.5	9.1	55	10
10	30	0	12.3	1.5	0	23.9	26	1.5	8.3	49	10

Abbreviations: TL, tunnel length; LE, lateral epicondyle; AC, anterior cortex; PC, posterior cortex; DC, distal cortex; TO, tunnel orientation with reference to line tangent to distal aspect of femoral condyles; CFP, clock-face reference position.

concluded that there is no risk with the anteromedial portal technique when the knee is flexed at least 130°. However, they did not specify the exact position of the starting femoral point. Furthermore, they used the same femoral starting drilling point in the transtibial and the anteromedial portal techniques as shown in their illustrations. Drilling the femoral tunnel at the anatomic position is not safely accomplished with the TTT.[11,12] Placement of a low femoral tunnel, which could not have been reached with a TTT, was rigorously performed in all the specimens in our study. Therefore it can be speculated that what Pujol et al. placed was a high femoral tunnel near the high-noon point rather than performing an anatomic reconstruction.

In this study the evaluation of the notch-view radiographs and, most importantly, the direct evaluation of the intercondylar notch during the final dissection confirmed that the grafts were properly oriented around the anatomic insertional site at the 10-o'clock position and with 2 mm of posterior back wall, currently known as the high/low position and deep/shallow position, respectively. This is very similar to previous anatomic descriptions of the ACL femoral footprint.[18] It was also observed that the femoral tunnel angulations with reference to a line tangent to the distal aspect of the femoral condyles coincided with the results described in a previous study.[20] The clock-face reference method used for the femoral tunnel position has recently been criticized as a simple but inaccurate method of tunnel referencing.[22] It has been said that it only considers the high/low position but misses the shallow/deep reference. This may be correct when a double-bundle ACL reconstruction is being performed. In the case of single-bundle reconstruction, because the step femoral guide is always lying below the posterior wall at the very same degree of flexion, we believe that the cephalad/caudad orientation is the important factor in helping to perform tunnel placement in the clinical setting. In this sense the clock-face reference might still be valid.

The degree of knee flexion during drilling of the femoral tunnel is controversial. In this study the flexion angle for performing the femoral tunnel was set at 110°. Basdekis et al.[20] have recently shown that with 130° flexion or greater, the acuity of the tunnel with regard to the notch increases, leading to the graft increasing pressure on the anterior tunnel wall. Therefore they recommended 110° of knee flexion. This was also supported by recent work performed by Nishimoto et al.[23]

Basdekis et al.[20] have also recommended a minimum length of 25 mm for the femoral tunnel. In our study only 1 specimen showed a slightly shorter tunnel length. This could be partially explained by the fact that the moderate narrowing of the intercondylar notch forces excessive anterior placement of the femoral tunnel guide when it is used through the anteromedial portal, and consequently, the fixation device is also too anteriorly placed.

It has been shown that reconstructing the femoral tunnel at the center of the anatomic origin of the native ACL more closely restores rotational stability to the knee than does the standard tunnel reconstruction at the 11-o'clock position.[2,9,10]

There are some limitations to this study. Besides the aforementioned fact that we only performed the technique at a 110° knee flexion angle and the small sample size, radiographic lateral projections were not obtained. Thus the anterior-posterior situation of the femoral tunnel could not be evaluated radiographically. Nevertheless, the presence of a 2-mm posterior wall was confirmed under direct evaluation in the specimens. In addition, how varying the drill angles for the Cross-Pin insertion could affect the results was not studied. Finally, neither interobserver nor intraobserver reliability was calculated for the measurements.

Fixation of the graft on the femoral side with the Cross-Pin device, which was initially developed for an upper femoral tunnel, may lead to iatrogenic lesions when the femoral tunnel is lowered. In this study we followed the same tunnel length recommendations as in the original placement of the graft (11 o'clock). A 30-mm femoral tunnel showed a high risk of injury to the LCL as well as to the PT. In 2 of the 10 specimens studied, the Cross-Pin directly pierced the LGT. Nevertheless, these injuries may have no clinical relevance. On the other hand, this technique proved to be safe with respect to the PN, leaving a minimum distance of 24 mm. We do not recommend the technique used in this study because of this risk of injury to the important lateral stabilizers of the knee. One of the alternatives is to change to a femoral fixation method that was previously shown to be safe.[24] Another possibility might be to adapt the technique of the Cross-Pin system to a more lateralized fixation. This might hypothetically be accomplished with a longer femoral tunnel or with further knee flexion. Nevertheless, further basic research should be done before a broad recommendation can be made.

CONCLUSIONS

Fixation of hamstring graft with the Cross-Pin system, originally designed for transtibial drilling when performing femoral tunnel placement from the anteromedial portal at 110° of knee flexion and with a tunnel length of 30 mm, shows a high risk of injury to the LCL. The PT and the LGT may also be injured.

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