The Safe Zone for TransFix Fixation in Anterior Cruciate Ligament Reconstruction Using the Anteromedial Portal Technique

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Purpose: The risk of neurovascular injury is inherent to cross-pin femoral fixation for anterior cruciate ligament reconstruction and has not been evaluated using the anteromedial portal technique; therefore, we determined a safe zone of cross-pin drill angles. **Methods:** Five cadaveric midthigh to midknee specimens underwent anterior cruciate ligament reconstruction by use of the anteromedial portal to drill the femoral tunnel and a cross-pin femoral fixation system. Guide pins were passed through the femur at −40°, −20°, 0°, and +20°, with 0° being the coronal plane bisecting the femoral shaft, negative angles when the guide pin started posteriorly, and positive angles when the guide pin started anteriorly. Distances between the guide pin and saphenous nerve, femoral artery, and peroneal nerve were measured. The neurovascular structures were considered safe if the guide pin did not pass within 10 mm of the structures. **Results:** The mean distance from pin to saphenous nerve was 74, 61, 21, and 24 mm at −40°, −20°, 0°, and +20°, respectively; pin to femoral artery was 100, 85, 59, and 51 mm, respectively; and pin to peroneal nerve was 40, 50, 65, and 76 mm, respectively. The safe zone for the saphenous nerve was violated at 0° and +20° in 2 of 5 knees, and the safe zone for the femoral artery was violated at +20° in 2 of 5 knees. **Conclusions:** We have shown that a 20° safe zone of rotational angles about the axis of the femoral tunnel, from −40° to −20°, minimizes the risk of damage to the saphenous nerve, femoral artery, and peroneal nerve. **Clinical Relevance:** Intraoperative guide-pin angle measurement can be made in reference to the coronal plane of the femur to guide safe drilling of the TransFix guide pin (Arthrex, Naples, FL).

The desire to improve clinical outcomes of anterior cruciate ligament (ACL) reconstruction has prompted the evaluation of methods for ACL graft fixation.[1,2] Although there is no consensus regarding the best method for femoral fixation, evidence from biomechanical and clinical studies supports the use of cross-pin fixation in ACL reconstruction.[1,3-7] Particularly, the TransFix device (Arthrex, Naples, FL) provides stronger and stiffer fixation compared with other cross-pin devices.[8,9] However, use of this device requires passing a guide pin across the distal femur, which creates a risk of injuring neurovascular structures that traverse the knee. A guiding device rotates the pin about an axis created by the femoral graft tunnel, which enables the surgeon to aim the pin in a direction that minimizes the risk of injury.[10]

Because the femoral tunnel forms the axis of rotation for the guide device, variations in femoral tunnel position and 3-dimensional (3D) orientation would likely affect the position and 3D orientation of the TransFix guide pin. Femoral tunnel position and 3D

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orientation have been shown to vary according to surgical technique.[11] Drilling the femoral tunnel through a previously established tibial tunnel (the transtibial technique) often results in a more vertical tunnel placed at or near the 11-o'clock position within the lateral femoral condyle, whereas drilling the femoral tunnel through an anteromedial (AM) arthroscopic portal (the AM portal technique) often results in a more oblique tunnel placed approximately at the 9:30 to 10-o'clock position within the lateral femoral condyle.[12,13] A femoral tunnel higher on the clock face (i.e., the 11-o'clock position) might lead to a more horizontal cross-pin tunnel, whereas a femoral tunnel lower on the clock face (i.e., the 10-o'clock position) might lead to a more vertical cross-pin tunnel.

A recent study described the safe range of drilling angles for the TransFix guide pin using a transtibial femoral tunnel.[10] Whereas this study offers important insight into the safety of the device, it is not clear whether the established safe range applies to its use with the AM portal technique, given the differences in tunnel position and 3D orientation between the 2 techniques. Therefore we aimed to determine the safe range of drilling angles using the TransFix device for femoral fixation and the AM portal technique for drilling the femoral graft tunnel. We hypothesized that there was a safe range of angles that minimized the risk of damage to the neurovascular structures surrounding the knee joint.

METHODS

Five right extremities from midthigh to midleg were used for this study. None of the knees had undergone previous surgery. After thawing to 25°C, the most proximal portion of the femur was mounted on a leg holder so that the shaft of the femur was parallel to the floor and the leg flexed to 90°.

The anterolateral portal was placed just lateral to the patellar tendon at its attachment to the patella. The AM portal was placed just proximal to the anterior horn of the medial meniscus and at the most anterior aspect of the medial femoral condyle. Once the ACL was identified as intact, it was resected and its attachments preserved. With the knee in maximal flexion (120°), the center of the ACL footprint was identified and confirmed by each of the investigators. In each knee the center of the footprint was located at approximately the 9:30 to 10-o'clock position. With the knee in maximal flexion, a guide pin was inserted through the AM portal and positioned over the ACL footprint center by use of a 5-mm offset guide. A 9-mm can-

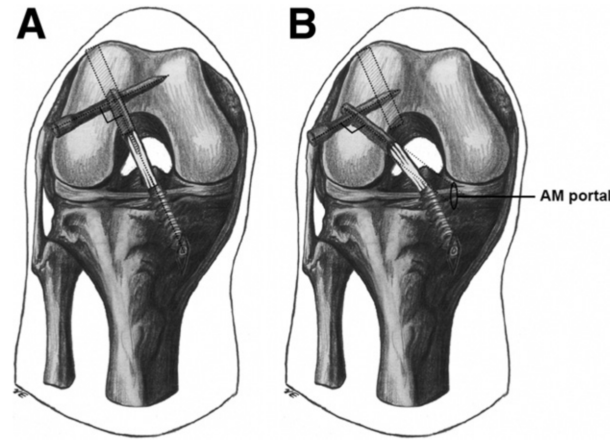

FIGURE 1. Different femoral tunnel placement techniques. (A) Femoral graft tunnel with transtibial technique. Placement of the femoral graft tunnel is restricted by the orientation of the tibial tunnel and often leads to placement at or near the 11-o'clock position. (B) Femoral graft tunnel with AM portal technique. The femoral tunnel can be placed closer to the 9:30 to 10-o'clock position favored by some surgeons.

nulated reamer was drilled over the guide pin to a depth that left 5 mm of lateral cortical bone (Fig 1). The posterior cortex remained intact in all specimens.

Once the femoral tunnel was drilled, the legs were partially dissected to identify the pertinent neurovascular structures. Incisions were made from superior to inferior along the medial, posterior, and lateral aspects of the knee. Medially, the saphenous nerve was identified deep to the subcutaneous tissue. Posteriorly, the soft tissue was separated until the femoral artery was identified. Laterally, skin and subcutaneous connective tissue were dissected until the peroneal nerve could be identified from the biceps femoris tendon and the fibular neck. Care was taken to preserve the in situ positions of these structures. Minimal incisions were made, and the smallest amount of tissue was perturbed to identify the structures and measure the distance between the structures and the guide pin.

Next, a TransFix drill guide was inserted through the AM portal into the graft tunnel. The guide was rotated about the axis of the femoral tunnel until its sleeve became coplanar with the coronal plane bisecting the femoral shaft (Fig 2). Once the position of the sleeve was independently verified as coplanar by all 4 authors, this position was set at 0°. The pin sleeve was pressed firmly against the lateral femur. A 3-mm cross-pin drill guide was inserted through the sleeve and then passed through the femur and out through the skin medially.

The shortest distances between the cross-pin guide pin and the structures studied were measured with a

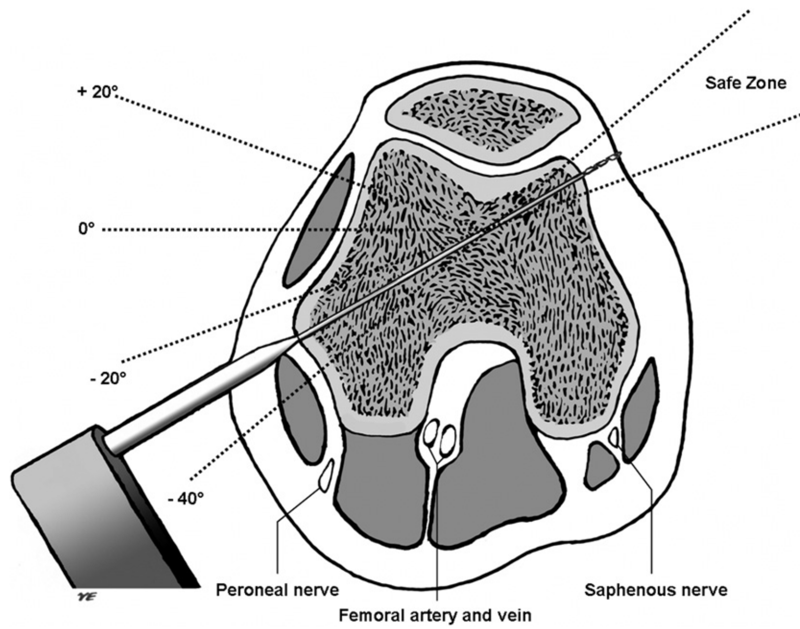

FIGURE 2. Passing guide pin through lateral femoral cortex by AM portal technique. The drill guide was rotated about the axis of the femoral tunnel. The coronal plane that bisected the femoral shaft was defined as the 0° plane. Positive angles (+20°) correspond to rotation of the guide anteriorly; negative angles (−20° and −40°) correspond to rotation of the guide posteriorly.

ruler with 1-mm accuracy. The shortest distances between the guide pin and saphenous nerve and between the guide pin and peroneal nerve were lines that perpendicularly bisected the cross pin at its medial and lateral exit points, respectively. The shortest distance between the guide pin and femoral artery was a line between the near aspect of the artery and the guide pin's medial exit point from the femur.

After measurement, the guide pin was removed. With the use of a goniometer, the guide pin was rotated 20° clockwise (anteriorly) from the 0° position about the axis of the femoral graft tunnel so that the guide pin was oriented in an anterolateral-to-posteromedial direction. This position was designated as +20°. The guide pin was redrilled and distances remeasured. This process was repeated with the guide pin rotated 20° and 40° counterclockwise (posteriorly) from the 0° position about the femoral graft tunnel axis (−20° and −40° positions, respectively). In these positions the guide pin was oriented in a posterolateral-to-AM direction.

Distance measurements from all 5 knees were grouped according to the structure being measured and the angle between the guide pin and the horizontal. Mean distance and standard deviation were calculated. We considered the 3 neurovascular structures to be safe if the cross pin did not come within 10 mm at any point. We used a sample of 5 specimens because previous work suggested that a sample size of 5 and safe zone of 10 mm or greater enable detection of trends toward increased or decreased risk of neurovascular injury by use of 20° increments for rotational angle.[10] No power analysis was performed before the study.

RESULTS

The mean distances ± standard deviations between the guide pin and the saphenous nerve at −40°, −20°, 0°, and +20° were 74 ± 30 mm, 61 ± 28 mm, 21 ± 16 mm, and 24 ± 19 mm, respectively. The guide pin passed within 10 mm of the saphenous nerve in 2 of the 5 knees at 0° and in 2 knees at +20° (Table 1). One of the knees had safe-zone violations of the saphenous nerve at both 0° and +20°. The saphe-

TABLE 1. *Distance Between Guide Pin and Saphenous Nerve*

	Distance (mm)				
Drill Angle	Knee 1	Knee 2	Knee 3	Knee 4	Knee 5
−40°	82	60	95	30	105
−20°	62	50	85	20	90
0°	17	8*	35	3*	40
+20°	50	5*	10*	20	35

NOTE. As the drill angle became more positive, the guide pin passed increasingly close to the saphenous nerve until it violated the 10-mm safe zone at 0° and +20°.
*Safe zone violation.

TABLE 2. *Distance Between Guide Pin and Femoral Artery*

Drill Angle	Distance (mm)				
	Knee 1	Knee 2	Knee 3	Knee 4	Knee 5
−40°	90	120	87	130	72
−20°	80	115	70	110	50
0°	25	80	60	100	30
+20°	8*	60	60	115	10*

NOTE. As the drill angle became increasingly positive, the guide pin passed increasingly close to the femoral artery until it violated the 10-mm safe zone at +20°.
*Safe zone violation.

nous nerve was safe between −40° and −20° in all specimens.

The mean distances ± standard deviations between the guide pin and the femoral artery at −40°, −20°, 0°, and +20° were 100 ± 24 mm, 85 ± 27 mm, 59 ± 32 mm, and 51 ± 44 mm, respectively. The guide pin passed within 10 mm of the femoral artery in 2 of the 5 knees at +20° (Table 2). The femoral artery was safe between −40° and 0° in all specimens.

The mean distances ± standard deviations between the guide pin and the peroneal nerve at −40°, −20°, 0°, and +20° were 40 ± 13 mm, 50 ± 17 mm, 65 ± 15 mm, and 76 ± 20 mm, respectively. The peroneal nerve was safe at all angles between −40° and +20° in all specimens (Table 3).

DISCUSSION

Our data suggest that orientation of the guide pin posterior to the coronal plane of the femoral shaft between −40° and −20° of rotation about the femoral tunnel axis minimizes the risk of injury to the saphenous nerve, femoral artery, and peroneal nerve. Our results support the hypothesis that the risk of injury to potentially vulnerable neurovascular structures of the knee is minimized by orienting the cross pin within a range of drill angles.

The safe zone for the AM portal technique established in our study is identical to that of the transtibial technique.[10] It is possible that the differences in cross-pin tunnel position and orientation between the 2 techniques for femoral tunnel drilling do not significantly alter the safe range of drill angles. However, there may be differences in the safe-zone angles that are too small to detect by use of 20° increments. Elucidation of any putative differences would be possible by use of smaller drill-angle increments, although such increments would have to be reproducible in the surgical setting to have clinical significance.

Our study contributes to the growing literature describing the risk of intraoperative injury from cross-pin femoral fixation. Pujol et al.[14] showed an increased risk of injury to the fibular collateral ligament (FCL) by the TransFix cross pin when using the AM portal technique compared with the transtibial technique for femoral tunnel drilling in a study using 20 knees. They also found a trend of decreasing risk of FCL injury with increasing knee flexion angle.[14] In our study all drilling was performed at maximal knee flexion (approximately 120°), and we did not observe any violations of the FCL. Our data support the use of cross-pin drilling with the knee in maximal flexion. Castoldi et al.[15] established that the risk of injury to the lateral femoral condyle articular cartilage is high when using a cross-pin system that uses 2 cross pins (RigidFix; Mitek, Norwood, MA) and an AM portal technique for femoral tunnel drilling in a study using 20 knees. On the basis of their results, the authors did not recommend using the RigidFix system with the AM portal technique. We did not observe any injuries to the lateral femoral condyle articular cartilage in our study. This may be attributable to the greater mean depth of our femoral tunnels (34 mm compared with 30 mm in the study by Castaldi et al.) and the use of a single cross pin (TransFix) instead of 2 pins (RigidFix). Hantes et al.[16] described a technique for TransFix fixation using the AM portal technique for femoral tunnel drilling. They reported no fixation failures in a sample of 30 procedures. We used a similar technique for femoral tunnel positioning and drilled femoral tunnels to a similar depth.

The drill angles used in our study are reproducible in the surgical setting. We defined the 0° plane as the midcoronal plane of the femoral shaft. This plane can

TABLE 3. *Distance Between Guide Pin and Peroneal Nerve*

Drill Angle	Distance (mm)				
	Knee 1	Knee 2	Knee 3	Knee 4	Knee 5
−40°	45	60	33	35	25
−20°	60	75	40	45	32
0°	65	90	55	65	50
+20°	85	100	70	80	45

NOTE. Increasingly positive drill angles resulted in increased distance between the guide pin and the peroneal nerve. The safe zone of the peroneal nerve was not violated between −40° and +20°.

be approximated by visual inspection and by palpation of the medial and lateral femoral epicondyles. Rotation of the cross-pin drill guide posteriorly (counterclockwise for right knees and clockwise for left knees) so that the guide pin is aimed in an anterior and medial direction corresponds to negative drill angles. The 20° range between −40° and −20° is sufficiently large to ensure confident cross-pin placement when accurate measurement of angles can be difficult.

In determining the cross-pin drill angle, one must also consider the stability of the cross-pin fixation. A relatively vertical cross-pin tunnel may have reduced length compared with a relatively horizontal one and, therefore, may not adequately contain the entire pin. This point is highlighted by reports describing the need to surgically remove broken or protruding cross pins.[17-20] Although our study did not evaluate the stability of the cross-pin fixation, it is likely that the obliqueness of the cross-pin tunnel depends partly on the obliqueness of the femoral graft tunnel and partly on the rotational angle of the cross-pin tunnel.

There were a number of limitations to our study. The small sample size (N = 5) limits the extent to which our data can be generalized to the entire population seeking ACL reconstruction. In addition, because we used cadaveric knees that had been transected at the midthigh and midleg, it is possible that the soft tissues became distorted relative to their normal positions in vivo. To minimize this effect, we dissected as little soft tissue as possible to make distance measurements. In the future, it would be beneficial to compare the safe zones of cadaveric knees with both transtibially drilled femoral tunnels and femoral tunnels drilled through an AM portal, with the use of more samples for each group. This would allow for comparison of the 2 techniques while controlling for anatomic variation.

CONCLUSIONS

We have shown that a 20° safe zone of rotational angles about the axis of the femoral tunnel, from −40° to −20°, minimizes the risk of damage to the saphenous nerve, femoral artery, and peroneal nerve.

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