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Tunnel collision during simultaneous anterior cruciate ligament and posterolateral corner reconstruction

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Abstract

Purpose   To verify the safest angle to drill femoral tunnels in simultaneous anterior cruciate ligament (ACL) and posterolateral corner (PLC) reconstructions to minimize the risk of tunnel collision and to examine the relationship between lateral femoral condyle (LFC) width and tunnel collision occurrence.

Methods   Ten fresh-frozen cadaveric knees were used. In each knee, anatomical single-bundle ACL femoral tunnels were arthroscopically drilled at 120 and 140 degrees of flexion, and tunnels for popliteus tendon (PLT) and fibular collateral ligament (FCL) were drilled at 20° axial/20° coronal angulations and 10° axial/30° coronal angulations. Three-dimensional computed tomography exams of the knees were performed. The presence of tunnel collision was evaluated, and the minimal distance between tunnels and the LFC width was measured.

Results   Risk of tunnel collision was significantly increased if FCL and PLT tunnels were drilled at 10° axial/30° coronal angulation ($P < 0.05$). Tunnel collision was noted in only one knee when FCL and PLT tunnels were drilled at 20° axial/20° coronal angulations. Knees with smaller LFC width had significantly higher risk for tunnel collision ($P < 0.05$).

Conclusion   Drilling PLT and FCL femoral tunnels at 20° axial/20° coronal angulation is a safe positioning for simultaneous ACL and PLC reconstructions. However, in smaller knees, the risk for tunnel collision could be greater. Surgeons should consider the possibility of tunnel collision when performing simultaneous ACL and PLC anatomical reconstruction, especially in knees with a small LFC width where the risk for tunnel collision could be greater.

Keywords   Knee injuries · Ligaments · Articular · Surgery

Introduction

The fibular collateral ligament (FCL) and the popliteal tendon (PLT) are considered the primary stabilizers of the knee posterolateral corner (PLC) [17, 22]. However, the popliteofibular ligament should be included in anatomical reconstructions of grade III posterolateral knee injuries in order to restore normal internal rotation [15]. Data from recent literature inform that PLC injuries can occur associated with anterior cruciate ligament (ACL) lesions at a frequency of 7.5–12.5 % [10, 14].

If PLC lesions are not diagnosed and treated, they may affect the ACL reconstruction results [8, 26]. Therefore, PLC and ACL lesions should be treated simultaneously, if these instabilities occur together [13, 14].

The current trend is that ACL reconstructions should be performed anatomically, looking for functional restoration of the ACL to its native dimensions, collagen orientation and insertion sites [27]. In this type of reconstruction, the femoral tunnel is more horizontal and closer to the FCL and PLT origins [20].

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In patients with complex ligament injuries, the multiple tunnels for soft tissue grafts may increase the risk of femoral condyle osteonecrosis or fracture [4, 24]. In these cases, single-bundle reconstruction is recommended [21], with the femoral tunnel entry point at the ACL anatomical origin centre, since biomechanically there is recovery of rotational stability close to normal knees in that position [18, 23].

Tunnel convergence is greater in combined anatomical ACL and PLC reconstruction, and it may lead to graft disruption and fixation loss [7]. It has been suggested that PLT tunnels should be drilled at 30° axial/30° coronal angulations, and FCL tunnels should be drilled at 30° axial/0° coronal angulations when posterolateral reconstructions are performed in combination with concomitant anterior cruciate procedures, but different degrees of knee flexion at the time of femoral tunnel drilling for ACL reconstruction were not evaluated [7].

The possible relationship between the lateral femoral condylar width and tunnel collision in combined ACL/PLC reconstruction was considered in one study using synthetic femurs [19] and in another one using human knees, where ACL tunnel trajectory was 0° in the sagittal plane and 40° in the coronal plane, but without any reference to the knee flexion angle for ACL femoral tunnel reaming [25].

Thus, a study with human knees is needed to test the safety of different femoral tunnel drilling angles for anatomical ACL reconstruction when concurrent PLC reconstruction is performed and to evaluate the impact of lateral femoral condyle (LFC) width on tunnel collision.

Verifying the safest angle to drill femoral tunnels for simultaneous ACL and PLC reconstruction to minimize the risk of tunnel collision was the first purpose of this paper. The second goal was to examine the relation between LFC width and tunnel confluence occurrence.

Materials and methods

Ten fresh cadaver knees were used, six males and four females, with ages ranging from 42 to 68 years. There were seven left and three right knees. All had the ACL intact, and none presented macroscopic evidence of arthrosis.

The femoral ACL tunnels were drilled arthroscopically, with the arthroscope located on the anteromedial portal, and tunnel perforations were made through an accessory anteromedial portal, inferior and medial to the anteromedial portal.

The centre of the ACL femoral insertion was marked with a bone pick, at the anteromedial (AM) and posterolateral (PL) bundles insertions junction, on the bifurcated crest [6, 28]. Two perforations through the LFC were made at this point with 2.5-mm guide wires; one of them was drilled with the knees with 120° of flexion and the other
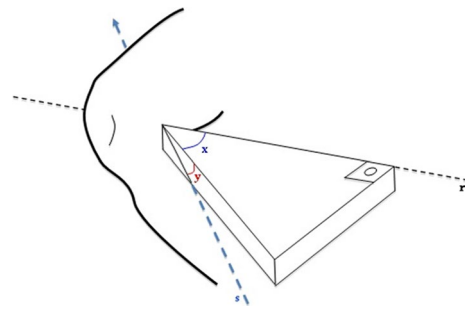

Fig. 1 Schematic representation of the wood model at the lateral face of a left knee. r = the transepicondylar axis, s = tunnel direction, x = coronal plane angle measurement, y = axial plane angle measurement
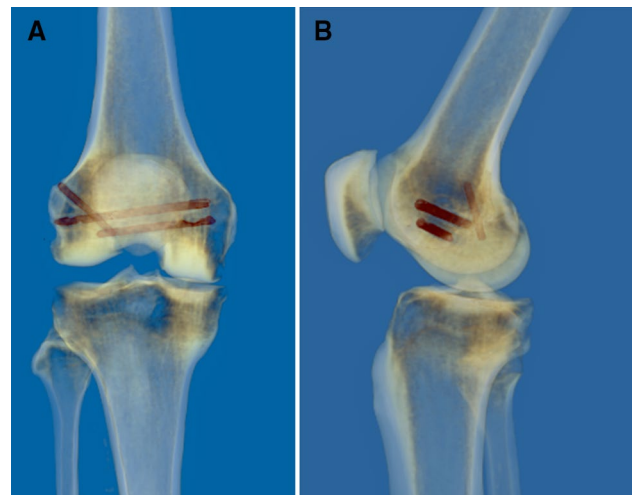

Fig. 2 **a** Anteroposterior transparent tomography image showing the tunnels in *red*. **b** Lateral view transparent tomography image showing the tunnels in *red*

with the knees flexed at 140°. Both guide wire perforations overpassed the lateral femoral cortex. Subsequently, guide wires were used in each of the two 2.5-mm drilled holes, and a cannulated drill increased their diameter to 8 mm until they overpassed the lateral femoral cortex.

The skin, subcutaneous tissue and fascia lata were removed, and the FCL and PLT femoral insertions were identified, as described by LaPrade et al. [12]. The osseous insertions centres of these ligaments were drilled with 2.5-mm-diameter guide wires with a 20° axial/20° coronal angle and with a 10° axial/30° coronal angle until it crossed the medial femoral cortex. Then, a 7-mm-diameter cannulated drill increased the perforation width made with the guide wires.

Two wood models in the form of a right-angled triangle were used in order to standardize drilling angles of guide wires (Fig. 1). The models were kept perpendicular to the ground with their apex pointed to the FCL or PLT femoral

insertion site in the coronal plane during tunnel reaming; a side of the triangle was always parallel to the transepicondylar axis.

After all tunnels were made, CT scans of the knees were performed in a Philips CT Brilliance tomograph, 64 channels, with 0.8-mm slices, and three-dimensional transparent images were obtained (Fig. 2). Tunnel angulations were measured in the CT images, and they had the same pattern, confirming the usefulness of wood models.

The occurrence of tunnel collision, the minimum distance between tunnels, the distance between the collision site and the LFC cortex and LFC width, calculated by the largest width average observed in frontal and axial planes, were evaluated with the aid of OsiriX Medical Imaging software. One of the authors examined the CT findings and randomly repeated the same measurements for the ten knees 20 days later. In order to determine the relationship between collision occurrence and LFC width, the knees were divided into two groups: wide knees, those with above average LFC width, and narrow knees, those with LFC width below average.

Statistical analysis

The Creative Research Systems® survey software was used to determine a 95 % confidence interval (95 % CI) sample size calculation. Inter-rater agreement statistic kappa with 95 % CI was calculated to measure intra-observer reliability. The Mann–Whitney test was used for statistical analysis, and 5 % was established as the significance level (α).

Results

The intra-observer 0.93 agreement (0.88–0.95) for the measurements of tunnel collision and LFC width was considered strong. The confidence interval for the sample size was 30.99, which can be considered large.

The knee flexion angle did not significantly influence tunnel convergence. We noticed six convergences when knees were flexed at 120° (30 %) and eight convergences when they were flexed at 140° (40 %). Collision occurrence was significantly higher when tunnels were drilled with a 10° axial/30° coronal angle than when they were drilled with a 20° axial/20° coronal angle (60 % × 10 %; $P < 0.01$). Tunnel collision was verified in only one knee when they were drilled with a 20° axial/20° coronal angle.

There was confluence between ACL tunnel and FCL tunnel in only one knee, where the ACL tunnel was performed with the knee flexed at 120° and PLC tunnels were drilled with 10° axial/30° coronal angle; all other collisions occurred between ACL and PLT tunnels (Fig. 3). In other words, collisions between ACL and PLT tunnels happened
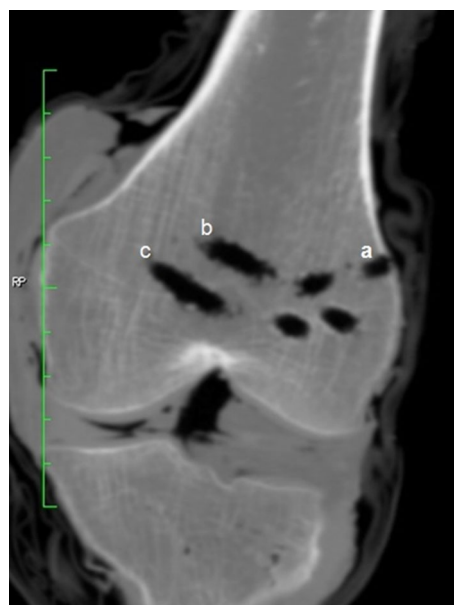

Fig. 3 Computed tomography image showing tunnel collision. a = ACL tunnel; b = FCL tunnel; c = PLT tunnel

Table 1 Minimum distance between tunnels in mm, at the different drilling sites performed

	Group 1	Group 2	Group 3	Group 4
Average	5.4 ± 1.9	2.5 ± 0.8	4.9 ± 2.0	2.5 ± 0.6
Minimum–maximum	2.2–7.1	1.4–3.4	1.1–6.9	2.0–3.3

Group 1: ACL tunnel perforation done with 120 degrees of flexion; FCL–PLT tunnel perforation done with 20° axial–20° coronal angle; Group 2: ACL tunnel perforation done with 120 degrees of flexion; FCL–PLT tunnel perforation done with 10° axial–30° coronal angle; Group 3: ACL tunnel perforation done with 140 degrees of flexion; FCL–PLT tunnel perforation done with 20° axial–20° coronal angle; Group 4: ACL tunnel perforation done with 140 degrees of flexion; FCL–PLT tunnel perforation done with 10° axial–30° coronal angle

in 13 of the 40 drilling combinations, and ACL–FCL tunnel intersection occurred in only one of the 40 perforation combinations (32.5 % × 2.5 %; $P < 0.01$).

In the non-confluent tunnels, the minimum average distance between tunnels was 4.41 ± 2.05 mm, ranging from 1.12 to 7.13 mm (Table 1). When tunnel collision occurred, the distance from the collision site to the LFC cortex ranged from 8.44 to 20.54 mm (Table 2).

The average LFC width in the studied knees was 33.5 ± 2.7 mm (30.0–37.5). The four wide knees had an LFC average width of 36.2 ± 1.2 mm (34.6–37.5), and in the six narrow knees, the LFC average width was 31.6 ± 1.4 mm (30.0–33.4). In the wide knees group, two collisions occurred in 16 combinations of the performed drillings, and in the narrow knees group, 12 collisions occurred in 24 reaming combinations (12.5 % × 50.0 %; $P < 0.01$).

Table 2 Distance in mm between the collision site and the lateral femoral cortex

	Group 1	Group 2	Group 3	Group 4
Average	8.4	14.2 ± 3.5	9.3	16.0 ± 3.5
Minimum–maximum	8.4–8.4	10.0–19.0	9.3–9.3	10.3–20.5

Group 1: ACL tunnel perforation done with 120 degrees of flexion; FCL–PLT tunnel perforation done with 20° axial–20° coronal angle; Group 2: ACL tunnel perforation done with 120 degrees of flexion; FCL–PLT tunnel perforation done with 10° axial–30° coronal angle; Group 3: ACL tunnel perforation done with 140 degrees of flexion; FCL–PLT tunnel perforation done with 20° axial–20° coronal angle; Group 4: ACL tunnel perforation done with 140 degrees of flexion; FCL–PLT tunnel perforation done with 10° axial–30° coronal angle

Tunnel convergence occurred in all combinations performed on one knee. In this knee, the LFC width was the lowest of the whole sample (30.0 mm).

Discussion

The most important finding of our study is that the chance of tunnel collision during ACL and PLC concurrent anatomical reconstruction may be minimized if the FCL and PLT tunnels are drilled with 20° axial and 20° coronal angle. However, in smaller knees, the risk for tunnel collision could be greater.

The collision between tunnels in simultaneous ACL and PLC reconstruction occur based on individual factors, such as the LFC width, and technical factors such as the chosen ACL reconstruction method, the degree of knee flexion during ACL tunnel drilling and the angle used for FCL and PLT tunnel reaming.

Anterior cruciate ligament reconstruction simulation with a single bundle was chosen because multiple soft tissue graft tunnels can increase the risk of osteonecrosis or femoral condyle fracture [4, 24], and because a single bundle is the ACL reconstruction choice in patients with multiple ligament injuries [21].

The ACL femoral tunnels were drilled with the knee flexed at 120° and 140° as the knee flexion angle influences the position of femoral drilling [2]. Also they were performed through an accessory anteromedial portal because tibial tunnel-independent technique allows a more anatomical femoral tunnel placement compared with transtibial technique [1]. The FCL and PLT tunnels were drilled in their insertion sites as described by LaPrade et al. [11].

The zero degree coronal angulation in PLC reconstruction tunnel perforation was avoided in our study because we realized that guide wires could penetrate the intercondylar notch at this angle. In the same way, we excluded the 40° axial angulation because in this position the guide wires

could penetrate the femoral trochlea [3]. Furthermore, graft fixation force decreases as fixation angle increases [5].

In a Medline research, only two articles were found regarding tunnel collision in ACL and PLC simultaneous reconstruction made with human knees [7, 25]. Other authors used synthetic models [3, 9, 19] that cannot reproduce the anatomical variation found in human beings, nor allow a precise ligament insertion site location.

There is a great variation in methods and angles for drilling tunnels described in the literature, which makes it difficult to compare study results. Camarda et al. [3] evaluated tunnel collision occurrence only in FCL and ACL PL bundle reconstructions. They found no collision when the FCL tunnel was drilled parallel to the distal condylar line and with 20° and 40° axial angulations.

Kim et al. [9] found that drilling is safe when FCL and PLT tunnels were made with 20° anterior and 10° proximal angles in transtibial double-bundle ACL reconstruction. Narvy et al. [19] investigated the frequency of intersection between a single-bundle ACL reconstruction and FCL tunnel. They reported that 40° anterior angulation and 20° proximal angulation produced the lowest risk of tunnel collision.

Gelber et al. [7] reported that to minimize tunnel collision risk the FCL tunnel should be performed with 30° axial and 0° coronal angulation, and the PLT tunnel was supposed to be drilled with 30° axial and 30° coronal angle. However, in their investigation, wires were left in situ and that could have affected the subsequent trajectory of the drilled wires.

Shuler et al. [25] concluded that FCL tunnel drilling should be made with neutral alignment in the coronal plane and with 40° axial plane angulation, and limiting the tunnel depth to 25 mm. However, following this rule, tunnel collision frequency was found in 29 % of their cases. We observed that when collision between the tunnels occurred, the distance from collision site to the LFC cortex ranged from 8.44 to 20.54 mm. Therefore, it would not be sufficient to limit the tunnel depth for the FCL at 25 mm to avoid collisions, as suggested by Shuler et al. [25].

Small LFC width may be a predictive factor for tunnel collision when performing concurrent LCA and PLC anatomical reconstruction, according to our findings. This is in conformity with Narvy et al. [19] and Shuler et al. [25] results and is in disagreement with Camarda et al. [3] outcomes.

Our study has some limitations. First, the sample size could be considered small, although it falls in between other papers that used human knees in their research [7, 25]. We anatomically reconstructed the ACL, with the femoral tunnel originating between the AM and PL bundles' insertion; the FCL and PLT tunnels were made in the

anatomical origin of these structures. Other techniques for ACL and the PLC reconstruction were not tested.

The tunnel diameter in ACL reconstruction may be larger than the one utilized for this study (8 mm). This diameter was chosen because it is the most frequently used graft size for single-bundle reconstruction [16].

The ACL tunnel entry point at the femur was the same for the tunnel drilled with the knee flexed at 120° as it was for the other performed with 140° of flexion, which eventually may change the guide wire trajectory in tunnel drilling.

The knees were not kept in a rigid fixed angle in our study; their degree of flexion was measured with a goniometer to simulate the operating room conditions. Finally, since we used human knees, we tested only four drilling combinations because more perforations could damage the knee structure.

Based on the results of the present study, surgeons should consider the possibility of tunnel confluence when planning to perform simultaneous ACL and PLC anatomical reconstruction. Perhaps it is advisable to check the LFC width preoperatively by computed tomography or magnetic resonance because tunnel collision risk may be higher in knees with a small LFC width.

Conclusion

The FCL and PLT tunnel reaming performed at 20° in the coronal axis and 20° in the axial plane, while simultaneously reconstructing the ACL, is a safe angulation to reduce the possibility of tunnel confluence. However, in knees with a small LFC width, tunnel collision risk may be higher.

Conflict of interest The authors report no conflict of interest.

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