Tunnel Intersection in Combined Anatomic Reconstruction of the ACL and Posterolateral Corner

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Abstract: Femoral tunnel intersection in combined anterior cruciate ligament and posterolateral corner reconstruction has been reported to be high. The purpose of this study was to examine the risk of intersection between an anatomic femoral anterior cruciate ligament tunnel created with a retrograde reaming device and femoral lateral collateral ligament reconstruction tunnels of varying trajectory in a synthetic femur model.

Injuries to the posterolateral corner (PLC) of the knee are infrequent but can cause severe disability due to damage to the articular cartilage and persistent instability. Although injury to the posterolateral structures can occur in isolation, coexisting injury to other structures, such as the menisci or the cruciate ligaments, is common. Unrecognized posterolateral rotatory instability has been shown to be a major cause of anterior cruciate ligament (ACL) reconstruction failure. This has led to an increased awareness of combined injuries and increased numbers of combined ACL and PLC reconstructions.

Numerous authors have published various surgical techniques for PLC reconstruction. Many tunnel configurations have been proposed, including a neutral lateral tunnel originating at the isometric point of the lateral epicondyle and tunnels originating from the anatomic origin of the lateral collateral ligament (LCL). In the setting of combined ligament reconstruction procedures, the close proximity of ACL and LCL tunnels in the lateral femoral condyle can cause bone weakening and tunnel collision, particularly when performing double-bundle ACL reconstruction. This can compromise graft function. Accordingly, the safest LCL tunnel trajectory has been recommended to avoid any proximal angulation in the coronal plane. However, when creating a concomitant, parallel tunnel for a popliteal tendon reconstruction, this trajectory may risk damage to the articular cartilage of the lateral femoral condyle or trochlea. In addition, this contradicts several popular PLC reconstruction techniques that recommend proximal and anterior angulation of both tunnels.

The accuracy of ACL tunnel placement is also important in combined ligament reconstruction. Gaditoka et al. recently compared transtibial ACL tunnel creation to outside-in and anteromedial portal techniques in a cadaver model and noted statistically significant improvements in the percentage of coverage of the ACL footprint by the femoral tunnel with the anteromedial portal and outside-in techniques. The center of the outside-in tunnel was found to most closely replicate the center of the ACL footprint. In addition, the exit point of outside-in tunnels on the lateral femoral condyle was farther away from the LCL origin (particularly in the anterior direction) than the anteromedial portal tunnels. This increased ability of outside-in tunnel creation to replicate the center of the ACL footprint and to better control tunnel trajectory relative to the lateral epicondyle may be clinically relevant in the reconstruction of a multiligament-injured knee.

The purpose of this study was to examine the risk of intersection between an anatomic femoral ACL tunnel created with an outside-in reaming device (FlipCutter; Arthrex, Inc, Naples, Florida) and femoral LCL reconstruction tunnels of varying trajectory in a synthetic femur model and to identify the best trajectory for safe tunnel...
placement. The authors hypothesized that using a retrograde ACL tunnel creation technique would reduce the risk of tunnel intersection and allow for a greater range of acceptable tunnel positions.

**MATERIALS AND METHODS**

Eighteen solid foam synthetic femurs (Pacific Research Laboratories, Inc, Vachon, Washington) were used as the model for tunnel creation. Nine were size large (36-mm lateral femoral condyle), and 9 were size medium (28-mm lateral femoral condyle). These synthetic femurs were mounted proximally to a custom-made frame, and anatomic ACL tunnels were drilled retrograde from the ACL footprint using the FlipCutter set at 110° from the ACL footprint using a goniometer. Several studies have noted increased tunnel collision with 30 mm tunnels compared with 25 mm tunnels; a 10-mm tunnel was therefore reamed to 25 mm deep using the calibration mechanism on the FlipCutter to prevent confounding due to tunnel depth.

Lateral collateral ligament tunnels were then created at the anatomic proximal attachment of the LCL (1.4 mm proximal and 3.1 mm posterior to the lateral epicondyle). Previous studies have shown that lateral tunnel trajectories greater than 40° in either the axial plane or coronal plane can result in ellipsoidal tunnels and thinned cortices about the tunnel opening; accordingly, tunnel trajectories were limited to this range. From the LCL starting point, 8-mm tunnels were drilled to a depth of 25 mm at either 0°, 20°, or 40° of angulation in either the proximal plane or the anterior plane (Figure 2). Specimens without obvious tunnel convergence underwent computed tomography (CT) scan with 3-dimensional reconstruction (2-mm cuts) (Aquilion16; Toshiba Medical Systems, Tustin, California) to determine the distance between the created tunnels or to determine whether an occult tunnel collision existed (Figures 3, 4). Radiographic measurements were conducted using the computer’s straight-line measuring tool to determine the tangent distance between the created tunnels.

**RESULTS**

Overall frequency of tunnel intersection was 5/9 (33%) in large femur specimens and 5/9 (56%) in medium femur specimens ($P=.34$; $\chi^2$). Among specimens without tunnel intersection, mean tunnel separation was 4.8±2.5 mm. Mean tunnel separation was 5.1±2.8 mm for the large-sized femora and 4.3±2.0 mm for the medium-sized femora ($P=.64$; Student’s $t$ test).

At 0° of anterior angulation in the axial plane, 5 (83%) of 6 specimens were noted to have tunnel intersection. At 20° of anterior angulation, 3 (50%) of 6 tunnels intersected. Mean tunnel separation among the remaining specimens was 4.2±1.5 mm. No intersection occurred with LCL tunnels created with 40° of anterior angulation, with a mean separation of 5.7±2.6 mm.

At 0° of proximal angulation, 1 (17%) of 6 specimens experienced tunnel intersection. Increasing degrees of proximal angulation to 20° and 40° produced a 50% and 66% rate of tunnel intersection, respectively. At these higher degrees of proximal angulation, high concomitant anterior angulation to 40° prevented tunnel intersection in both medium and large specimens.

Maximum tunnel separation was noted at 40° of anterior angulation and 0° of proximal angulation (9.6 mm in the large femur and 7.2 mm in the medium femur). However, the guide pin used to drill the LCL tunnel at this trajectory violated the trochlea in both medium and large specimens (Table).

**DISCUSSION**

This study demonstrates a decreased risk of tunnel intersection with greater anterior angulation and an increased risk of tunnel intersection with...
greater proximal angulation. These findings were particularly important in the medium-sized femora, which had overall higher rates of intersection, likely due to the smaller available volume for traversing tunnels. However, proximal angulation greater than 20° did not produce tunnel collision to the same extent as has been previously described. Proximal angulation of 20° or more was a safe configuration in the large femur when combined with 20° of anterior angulation and was safe in both femur sizes when combined with 40° of anterior angulation.

Two studies have previously evaluated tunnel collision in combined ACL–PLC reconstruction using synthetic femur models with study designs similar to that of the current study. Shuler et al. evaluated tunnel placement in 11 synthetic femurs. The ACL tunnel was placed in a standard manner but appeared to be non-anatomic on imaging, with the intra-articular tunnel aperture centered over the footprint of the anteromedial bundle rather than between the anteromedial and posterolateral bundle footprints. The LCL insertion point was anatomically located on the synthetic femurs, and then tunnels of varying axial and coronal angulation (0°-60°) were drilled from this starting point. The authors found that increasing the axial trajectory of the lateral tunnel from 0° to 40° was protective against tunnel collision and demonstrated that tunnel separation distance increased directly with axial angulation. Coronal angulation greater than 20° produced tunnel collision in all specimens. In a separate arm of the study, the authors compared LCL tunnels drilled at 40° anterior/0° proximal to control tunnels drilled at 0° anterior/0° proximal in 7 matched cadaver knees and noted a 29% collision rate with the more anterior tunnels compared with 43% in the control group. The authors concluded that the safest configuration for tunnel placement was 40° anterior and 0° proximal.

Camarda et al. performed a similar study of tunnel placement when the ACL was reconstructed using only the posterolateral bundle tunnel of a double-bundle technique concomitantly with reconstruction of the lateral collateral ligament in 36 synthetic femurs (18 large and 18 medium). As in the current study, 9 different guidewire

<table>
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<th>Specimen No.</th>
<th>Femur Size</th>
<th>PLC Angle, deg</th>
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Abbreviation: CT, computed tomography; deg, degrees; PLC, posterolateral corner.
orientations in the anterior and proximal planes were created at 20° intervals for the LCL tunnel. Similarly to Shuler et al., the authors demonstrated a significantly higher rate of tunnel collision with proximal angulation greater than 20°. No collisions were noted when the LCL tunnel was reamed at 0° of proximal angulation, irrespective of anterior trajectory.

Also similar to Shuler et al., the current authors noted maximal tunnel separation at 40° anterior and 0° proximal. This configuration resulted in violation of the trochlea in both medium and large specimens, although proximal angulation to 20° at the same anterior trajectory produced satisfactory tunnel separation. This finding suggests that proximal angulation may be protective of the trochlea when combined with significant anterior angulation.

However, the limitations of this laboratory model must be appreciated in making this determination. Variability of human femoral condyle size can greatly affect the risk of tunnel collision, and although 2 sizes of synthetic femur were used in the current study, in vivo tunnel creation may produce different findings. Similarly, in vivo retrograde reaming is based on intra-articular landmarks from the footprint of the ACL, which was not present in this sawbones model. Using a handheld goniometer for lateral tunnel placement may have an increased risk of variability compared with a well-controlled jig. Most importantly, the small sample size limits the generalizability of the current results to in vivo reconstructive procedures. Nonetheless, this study demonstrates the technical feasibility of a combined ACL-PLC reconstruction using a retrograde reaming device in a laboratory model. Increasing anterior angulation when combined with 25-mm LCL tunnels may help avoid tunnel intersection when performing such combined procedures, particularly in smaller-sized femora.

CONCLUSION

The results of this study provide evidence for safe LCL tunnel creation when using retrograde ACL reaming techniques in combined ACL and PLC reconstruction. Forty degrees of anterior angulation of the LCL tunnel produced the lowest risk of tunnel collision but at the risk of trochlear violation without concomitant proximal angulation. Therefore, optimal tunnel orientation is recommended at 40° of anterior angulation and 20° of proximal angulation.

REFERENCES