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Femoral footprint variation of the posterolateral bundle of the anterior cruciate ligament and double-bundle reconstruction

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ABSTRACT

Background: The study is aimed to observe the range of variation of the ACL PLB femoral footprint and investigate countermeasures for accurate femoral bone tunnel placement during double-bundle ACL reconstruction.
Methods: The femoral insertions of the anteromedial bundle (AMB) and PLB of the ACL were dissected in 30 male cadaveric knees. The ACL footprint on the lateral intercondylar wall (LIW) was observed, and the shape of the LIW, the resident ridge, the angle between the ACL long axis and femoral axis (AA), and the vertical distance from the center of the PLB to the lowest cartilage border of the LIW (PD) were measured.
Results: The area most populated by the ACL fibers was directly under the resident ridge. AA = 18.7° ± 15.25° with variation from −18° to 56°, and PD = 7.02 ± 1.47 mm with variation from 3.75 to 11.08 mm. Both discrete values were very large in both groups of data. There were two kinds of LIW: trapezoidal (8 knees) and triangular (21 knees). Both AA and PD values exhibited significant differences between the two types of LIWs ($P = 0.00$).
Conclusion: AA and PD vary among individuals. The insertions and centers of the PLB cannot be exactly anatomically determined with one size. For double-bundle ACL reconstruction, an individualized intraoperative footprint observation for fresh cases with footprint remnants, or resident ridge and anteromedial bundle-interval identification for old ACL tears, can be reasonable methods for posterolateral tunnel orientation.
Clinical relevance: Clinical relevance is observe the range of variation of the PLB femoral footprint for clinical double-bundle ACL reconstruction.

1. Introduction

Anterior cruciate ligament (ACL) tears are usually reconstructed by arthroscopic single-bundle reconstruction, but the ACL posterolateral bundle (PLB) is not reconstructed [2,13]. In recent years, double-bundle (DB) ACL reconstruction has aroused increasing attention. However, some studies reported that the repair effects of DB ACL reconstruction were not as favorable as, and even worse than, single-bundle reconstruction [10,14]. A variation of the ACL femoral footprint exists among individuals; anatomical variation of the ACL PLB is particularly large [9,12]. Therefore, understanding the range of variation of femoral PLB insertions is very important for arthroscopic DB ACL reconstruction. The anatomic study can describe variations of femoral PLB insertions, landmarks, and orientation of human knee samples. We hypothesized that we can accurately localize the PLB according to reference markers during arthroscopic DB ACL reconstruction.

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2. Materials and methods

2.1. Sample dissection and preparation

A total of 30 adult cadaveric knees were selected from 15 males aged 21 to 58 years. The part 20 cm above the knees was cut, and the tissues connecting the tibia and femur were isolated with the exception of the ACL. The ACL was cut off at the end of the tibia. The intercondylar fossa of the femur was cut longitudinally, and the medial condyle was removed to expose the ACL femoral insertion.

2.2. Sample measurements

The synovial membrane and fat surrounding the ACL insertion were removed, and the Blumensaat line, resident ridge (RR), and ACL anteromedial bundle (AMB) and posterolateral bundle (PLB) footprints were identified and marked. The shaft of the femur was fixed parallel to the ground; i.e., knee flexion at 90°. According to the ACL fiber orientation and fiber bundle composition, the range and center of the ACL footprint AM and PL were marked. The footprint of the 2-mm ACL stump was retained, and the long axis between the AM and PL centers

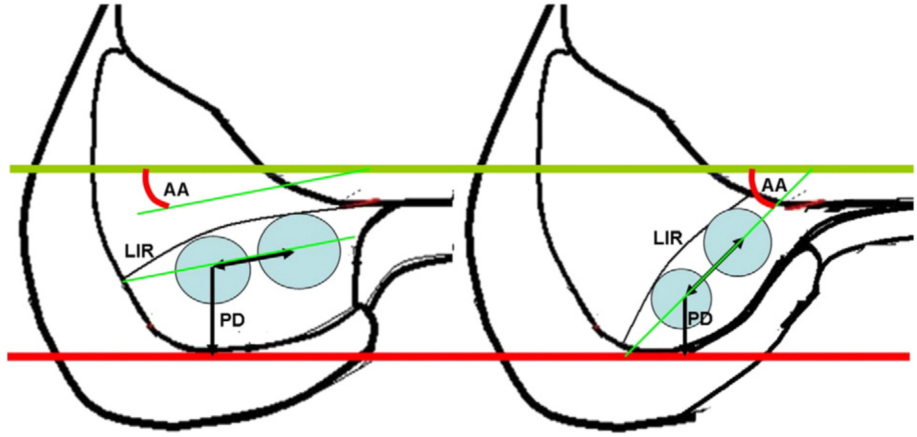

Fig. 1. Measurements of the posterolateral bundle footprint. Left: trapezoidal condyle; right: triangular condyle. AA: angle between ACL long axis and femoral axis; PD: vertical distance from center of PLB to lowest cartilage border of the LIW; RR: external intercondylar eminence.

was marked. The distance between the sample PLB footprint center and surrounding structures was measured using vernier calipers. The femoral lateral intercondylar wall (LIW) inferior border and posterior border cartilage range were marked using a marker pen. The ACL isolation, marking, and measurements were performed by one researcher. Each sample was photographed using a digital camera (5 000 000 pixels) and analyzed using Adobe Photoshop Elements 2.0 (Adobe Systems, San Jose, CA). RR, the angle between the ACL long axis (the line between the center of AM and PL footprints) and femoral axis (AA), and the vertical distance from the center of the PLB to the lowest cartilage border of the LIW (PD) were used to localize PLB. In addition, the shape of LIW was observed (Fig. 1).

2.3. Statistical analysis

Data were analyzed by mean comparisons using SPSS 18.0 software. A value of $P < 0.05$ was considered statistically significant.

3. Results

The ACL femoral footprint was localized below RR (Fig. 2) until the cartilage at the inferior border of the LIW can evidently distinguish the AMB from the PLB. ACL fibers were arranged from the surrounding to the center of the footprint. The functional center of the ACL DB (densest area of the fibers) was localized at the area below and parallel to the RR. RR was the upper boundary of the ACL DB footprint.

The range of variation of the ACL femoral footprint was large, and most of the footprints were oval-shaped, but the AA could be measured. The range of the AA was −18° to +56°, and the mean of the PD was 7.02 ± 1.47 mm with differences from 3.75 to 11.08 mm. Dissection results showed that 10 samples (10/30) exhibited differences of >2 mm than the mean PD value, and >3 mm than the mean PD value in six samples (Fig. 2, Table 1).

There were two types of LIW: trapezoidal (nine knees) and triangular (21 knees) (Fig. 3). Both AA and PD values exhibited significant differences between the two types of LIWs. Triangular cases exhibited small PD values (low PLB center) and sloped AA, but trapezoidal cases exhibited large PD values (high PLB center) and flat AA. The PD value was significantly lower in trapezoidal cases (7.60 ± 0.49 mm) compared with triangular cases (4.97 ± 0.58 mm; $t = -19.27$, $P = 0.001$), but the AA was significantly larger in trapezoidal cases (25.84° ± 11.22°) compared with triangular cases (0.47° ± 9.83°; $t = -6.57$, $P = 0.001$) (Table 2) (Fig. 4).

4. Discussion

Complete restoration of the ACL footprint is essential for ACL reconstruction [18]. The present study observed the morphological characteristics of the ACL femoral PLB footprint in 30 knee joint samples. As the result, we found that PLB footprint had great variations. Intensive attention on individualized localization of the PLB can clearly identify the PLB footprint.

A large number of studies have confirmed that the ACL functions by the AMB and PLB. During DB ACL reconstruction, femoral PLB localization is very important because transplant size, bone tunnel drilling, and angle are selected according to PLB localization [9,12]. Studies have reported that upon reexamination following DB ACL reconstruction, the PLB had been completely absorbed, which may contribute to the impingement factor [4,18]. In the present study, part of the PLB was torn and even absorbed upon reexamination following DB ACL reconstruction, which may have resulted from the low or posterior localization of the PLB bone tunnel.

During arthroscopy, the angle between the ACL footprint and the shaft of the femur was measured by flexing the knee to 90° so that the shaft of the femur was parallel to the tibial plateau; [i.e. the angle between the ACL long axis and tibial plateau (AA)].

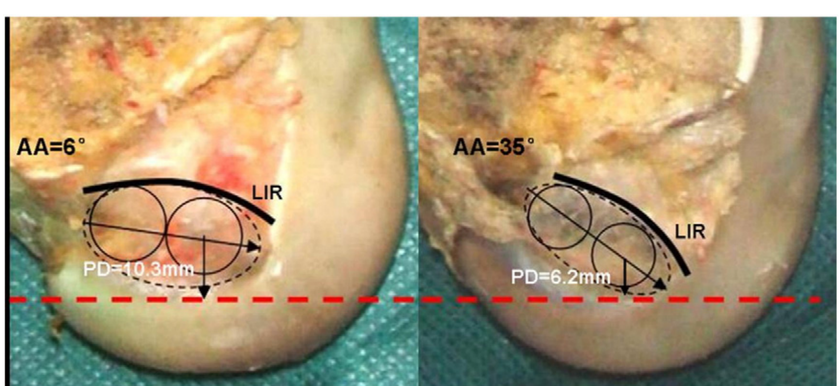

Fig. 2. Two types of LIW. Left: trapezoidal condyle; right: triangular condyle.