Original Article With Video Illustration

Isometric Characteristics of the Anterolateral Ligament of the Knee: A Cadaveric Navigation Study

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Purpose: To measure the variations in length during flexion and internal tibial rotation of the 3 different femoral insertions of the anterolateral ligament (ALL) while maintaining a fixed tibia insertion. **Methods:** Twelve fresh-frozen cadaver knees were analyzed using a navigation system. Maximal distance variations of the 3 different anatomic femoral insertions of the ALL were measured during knee flexion and internal tibial rotation at 20° (IR20°) and 90° (IR90°). The 3 different femoral attachments were, as published, at the center of the lateral epicondyle, distal and anterior from this position, and proximal and posterior. Each of these 3 femoral insertions was coupled to the same tibial insertion at the tibial margin, halfway between the tip of the fibular head and the prominence of the Gerdy tubercle. **Results:** During IR20°, variation in the distance between paired points is not different between the proximal-posterior, epicondyle, and distal-anterior femoral insertions. These variations were statistically different during IR90° for the 3 different femoral locations. In increasing degrees of flexion, there was a length decrease between paired points observed with the proximal-posterior position. A length increase was observed for both the epicondyle location and the distal-anterior location. **Conclusions:** The ALL did not reveal an isometric behavior at any of the femoral insertion locations but had different length change patterns during knee flexion and internal tibial rotation at 90°. The proximal and posterior to epicondyle femoral position is the only position with a favorable isometry, as shown by being tight in extension and in internal rotation at 20° and then relaxed when the knee goes to flexion at 120° and during internal rotation at 90°. **Clinical Relevance:** Clinical relevance is significant with respect to optimizing the femoral position of an ALL reconstruction.

See commentary on page 2025

Various attempts have been made to provide better rotational stability of the knee after anterior cruciate ligament (ACL) reconstruction. Although there are contradictory results with double-bundle ACL reconstruction technique,[1-3] additional extra-articular reconstruction generated renewed interest with recent investigations into the anatomy of the anterolateral ligament (ALL).[4] Authors agree on the existence of a separate ligamentous structure called the ALL, located on the lateral part of the joint and supposed to control tibial internal rotation near to knee full extension.[4-9] Although most authors agree on the tibial insertion located halfway between the tip of the fibular head and the prominence of the Gerdy tubercle,[4-7,9] its femoral attachment remains a subject of debate. Three different femoral locations have been described: at the lateral femoral epicondyle,[4] proximal and posterior to the lateral femoral epicondyle,[4-6] and distal and anterior to the lateral femoral epicondyle.[4,5,7,9] Some studies have already reported changes in length of the ALL during knee flexion/extension,[6,10-12] but its behavior during knee rotation in different degrees of flexion is still unknown.

The purpose of the study was to measure the variations in length during flexion and internal tibial rotation of the 3 different femoral insertions of the ALL

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while maintaining a fixed tibia insertion. Our hypothesis was that the different femoral insertions will exhibit different variations in length throughout the range of motion (ROM) of the knee.

Methods

This study involved fresh-frozen, unpaired, whole cadaveric lower extremities provided from a tissue bank after the local research ethics committee gave ethical approval. All 15 specimens available from the local tissue bank were considered for inclusion. Exclusion criteria were no examination signs of knee instability, previous arthrotomy or ACL reconstruction scars, and no signs of advanced osteoarthritis defined as frank osteophytes, gross deformity, or limited ROM. Twelve of 15 cadavers met the inclusion criteria, including 8 women and 4 men, with a median donor age of 76.4 years (range 64.5 to 87.2 years).

Specimens were thawed at room temperature 24 hours before dissection. Four 3.5-mm holes were drilled in the cortical bone of the femur and tibia to fixate the navigation system sensors.

To acquire the kinematic data, the Praxim navigation system (Medivision Surgetics system; Praxim, Grenoble, France) equipped with ACL logics software was used to measure the maximum variation of length during knee flexion and internal rotation at both 20° and 90° of flexion. This software is able to perform reliable measurements of maximal discrepancy changes in distance between a pair of points during specific maneuvers applied to the knee.[13]

The system is composed with an optical head integrated into the system, a pointer allowing simultaneous determination of anatomic landmarks, a piloting screen, and spherical sensors. It has been shown to be very precise, within 1° or 1 mm,[13] and acquires landmarks directly on the bone surfaces to determine the articular anatomy of the knee. The reference points used for this study were the intercondylar notch of femur, the lateral epicondyle, ACL femoral insertion, the intercondylar process of tibia, the center of each tibial plateau, and both the lateral and medial malleoli. The global method is based on the digitization of points with an optical 3D localizer. For the morphologic acquisitions, the system uses a method based on the registration of sparse point data within a 3D statistical deformable model. The ankle center is defined by the digitization of anatomic landmarks and the hip center is defined kinematically by determining the rotation center of the cloud of points created by the motion of the femoral cluster during an imposed cycle of the knee from 0° to 120° of flexion.

Knee dissection and implementation of the navigation system were done on the lower limb positioned with the hip flexed to 45°, the knee flexed to 90°, and the feet flat on table. During manual maneuvers, one examiner supported the thigh and maintained the pointer while another one supported the leg and applied the desired flexion or rotational maneuver (Fig 1).

Fig 1. Right lower limb fitted with the navigation system and the torque wrench during tibial internal rotation testing at 90° of knee flexion.

The lateral aspect of the knees was dissected according to the layered anatomy, and 3 femoral positions corresponding to the previously described ALL femoral insertions were noted by applying metallic pins (Fig 2). The first one was placed at the center of epicondyle, identified by its most prominent part. By moving 0.7 cm distal to epicondyle and then 0.7 cm anterior, a second one was placed 1 cm distal and anterior to the center of the lateral epicondyle. By moving 0.7 cm proximal to epicondyle and then 0.7 cm posterior, a third one was placed 1 cm proximal and posterior to the center of the lateral epicondyle.

A fourth metallic pin was positioned at the ALL tibial insertion, halfway between the tip of the fibular head and the most prominent part of the Gerdy tubercle and from 7 mm distal to the tibial rim, as a mean of the tibial reported insertions.[4-7,9] Thus, the 3 paired points studied were "epicondyle"/ALL tibial insertion, "distal-anterior"/ALL tibial, and "proximal-posterior"/ALL tibial (Fig 2).

For each paired point, the following tests were performed: knee motion from full extension to 120° flexion with the joint in a neutral rotational position provided by the navigation system, and tibial rotation from neutral rotation to maximal internal rotation under 30 N torque with the knee flexion fixed at 20° (IR20°) and then at 90° (IR90°). As the moment of force is the product of a force and its distance from an axis, which causes rotation about that axis, the 30-N torque (force) was provided by a dynamometric wrench triggering at 2 Nm (moment of force) applied to the distal leg through a fast clamp at a distance of 0.07 m (distance from the axis) from the rotation center of the tibia (Fig 1).

The distance between the paired points was continuously measured by the navigation system, but only the maximum change in distance between paired points for each of the 3 laxity tests was recorded for the study.