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AM bundle controls the anterior–posterior and rotational stability to a greater extent than the PL bundle — A cadaver study

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ABSTRACT

Background: The purpose of this study was to evaluate the influence of both bundles of the anterior cruciate ligament (ACL) on knee stability, anterior–posterior translation (APT) and internal (IR) and external (ER) rotation in cadaveric knees using a computer navigation system.
Methods: The APT, IR, and ER of the knees were recorded in the intact condition, the anterolateral bundle (AM) or the posterolateral bundle (PL) deficit condition and in the ACL-deficient condition. The KT-1000 arthrometer was used for APT evaluation. The measurement of rotational movements was done using a rollimeter. All tests were performed at 30°, 60° and 90° of flexion.
Results: At 30° of flexion: In the intact knee APT was 5.8 mm, IR 12.1°, ER 10.1°. After the AM was cut, the APT increased to 9.1 mm, IR to 13.9° and ER to 12.6°. After the PL was cut, the APT was 6.4 mm, IR 13.1° and ER 10.6°. After the AM and PL were cut, the APT was 10.8 mm, IR 15.7° and the ER was 12.9° on average.
Conclusions: The AM has a greater impact on the APT than the PL in all knee joint flexion angles. The PL does not resist the rotational stability more than the AM. The rotational stability is better controlled by both bundles of ACL as compared to one bundle of the ACL.
Clinical Relevance: This study acknowledges the fact that the both bundles of the ACL are importants for AP and rotational stability of the knee joint.

1. Introduction

The anterior cruciate ligament (ACL) consists of two functional parts that develop in the 16th week of gestation [1]: the anteromedial (AM) bundle and the posterolateral (PL) bundle [2–8]. Its anteromedial segment is inserted more medially and ventrally to the tibia. The fibers of the posterolateral bundle are attached to posterior and lateral parts of the ACL attachment to the tibia [9–12]. Depending on the knee flexion, the position of the femoral attachment of either bundle relatively varies from vertical orientation of both bundles in full extension to increasingly horizontal orientation in flexion. In flexion, the AM bundle is tightened and the PL bundle is more relaxed; in full extension, the AM bundle is more relaxed than the PL [13–16]. The Lachman and "pivot shift" tests are mainly used to determine the quality and functional condition of the ACL [8,17]. The Lachman test can be quantified subsequently using the KT-1000 arthrometer (MEDmetronic, San Diego, California).

This research aims to assess the effect of both ACL bundles (AM, PL) on the anterior–posterior and rotational stability of the knee joint. The following hypotheses were examined:

A) The AM bundle controls anterior–posterior translation (APT) more than the PL bundle.
B) The AM bundle controls the rotational stability more than the PL bundle.
C) With the intact ACL, the rotational stability is better controlled than when only the AM bundle is present.

2. Materials and methods

The experiment was performed on knee joints of 30 fresh cadavers (whole bodies), each being Caucasian, 55–90 years of age at the moment of death (average 75 years), without neither previous surgical treatment nor lower limb injury. On average, the specimens were dead for 18 h (range, 8–24 h) and had not been chemically treated.

The lower limb of each cadaver was fixed to the surgical table by a set of ropes. The cadaver's femur was fixed into a metal holder clamp. A self-cutting was applied to the distal part of the femur, which prevented rotational motions of the femur after being fixed by the belt. This mechanism was introduced to eliminate unintentional shifts

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of the femur, since the research was based on observation and analysis of the tibia movements experienced under various conditions.

An "iron shoe" was used for each of the cadaver's feet using plastic strips (Fig. 1). This shoe provided 100° dorsal flexion in the tibio-talar joint, eliminating the possibility of rotational movements in the ankle. A rollimeter (Aesculap, Tuttlingen, Germany) was fixed to the shoe in the axis of the tibia. This device provided rotational movements in the tibial axis. The knee joint flexion (30°, 60° and 90°) was secured by wooden wedges and controlled on the screen of navigation system.

A bicortical screw for tibial passive markers of the navigation was drilled into the ventral side of the tibia, 10 cm below the tibial tuberosity. Another screw was applied into the ventral side of the femur 15 cm above the upper edge of the patella in the same way. The optical computer-controlled navigation system Orthopilot (Aesculap, Tuttlingen, Germany) was used to determine the deviation of the tibia relative to the femur during APT and rotational movements in the knee joint (Fig. 2).

This navigation system uses a stereo-optical infrared camera to track locations of infrared light sources. Trackable light sources were passive markers. Computer software is able to locate and calculate positions of the markers relative to each other, as well as to the camera. By this means it was possible to record the stability of the knee joint (the Lachman test and the test of the internal and external rotation) before and after the ACL bundles were cut. The resolution of the motion measurements of this navigation system is less than 1 mm and degree. The manufacturer declares 100% accuracy if the position of the markers is recorded correctly.

Using the pointer with passive markers, the data were acquired from the tibial tuberosity, anterior tibial cortex and the medial and lateral edge of the tibial plateau, followed by recording the data into the navigation system while both in 90° flexion and in full extension of the knee joint and registering the kinematic data for the transfer of the knee joint between the above mentioned states (90° flexion, full extension).

After recording all this data into the navigation system, an internal rotation (IR) of the knee joint was performed using the rollimeter attached to the metallic shoe with the force of 2.5 Nm. The value of deviation shown by the navigation was recorded. The same process was then repeated using the external rotation (ER) of the knee joint. Finally, the tibial APT was performed, using the KT-1000 (MEDmetronic, San Diego, California) set to force of 30 lb, repeated for 30°, 60° and 90° flexion of the knee joint. The changes of the APT were measured by the computer navigated system. Subsequently, a very limited medial patellar approach was used without compromising any stabilizing structure (the incision was performed parallel with the medial border of patellar ligament). Using an arthroscopic camera system, the ACL was located.

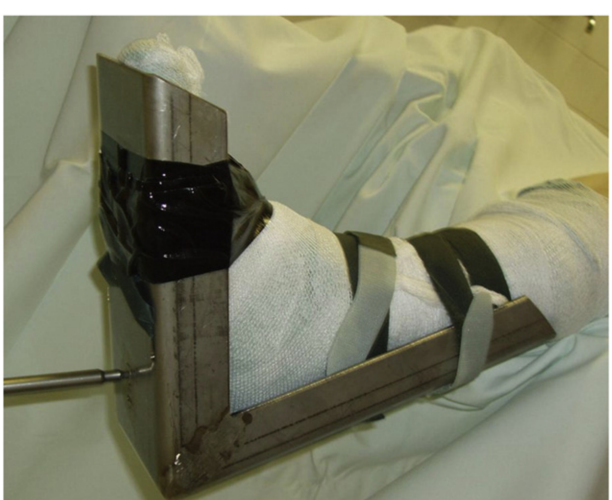

Fig. 1. "Iron shoe" mounted to the cadaver foot providing 100°dorsal flexion in the tibio-talar joint.

Both bundles of the ACL were identified and one of the bundles was cut. Both the order in which bundles were cut and the selection of the limb were determined by permuted block randomization. After having cut the first randomly chosen bundle, the measurement was repeated as stated above with only one functional ACL bundle. These measurements were also repeated three times for each condition. After recording all the desired data, the remaining ACL bundle was cut and the measurement process was repeated once again for the ACL-deficient knee joint.

After having collected all data on absolute values of deviations in APT of the tibia relative to the femur (in mm), internal and external rotations (in degrees), all of it separately with the joint being in 30°, 60° and 90° flexion, the instability data were compared for ACL-intact, AM-deficit, PL-deficit, and ACL-deficient knee. The order of the tests was the following: in 30° flexion: APT, IR and ER for ACL-intact knee, then the same process for 60° and 90° flexion; one part of the ACL was cut and the APT, IR and ER in 30° were repeated, then in 60° and 90°; finally followed the same process for ACL-deficient knee.

2.1. Statistical analysis

All data were evaluated by STATISTICA 9.0 software. The description of the deviation of movement in millimeters or in degrees included mean, standard deviation and range for continuous variables. Multivariate analysis of variance (MANOVA) and one way analysis (ANOVA) were used. Differences in statistical significance were determined by an paired Student *t*-test for a mean value in each phase. The p value <0.05 was considered statistically significant.

3. Results

The data obtained with the KT-1000 arthrometer resulted in conclusion of the AM bundle that controls the *APT* of the knee joint more significantly than the PL bundle and this is valid for all degrees of knee joint flexion (p value <0.05). AP instability of the knee joint is the highest after the cut of both ACL bundles (p value <0.05). With increasing knee joint flexion, the absolute AP instability values (mm) decrease (Table 1).

Rotation movements measured using the rollimeter proved that both bundles of the ACL control IR and ER in the same way. The *IR* was controlled by both ACL bundles, in all degrees of flexion, almost identically (without statistical significance). The values showed slightly higher levels of instability after cutting the AM bundle (Table 2). The data for the *ER* showed similar values as for the IR. The ER was less influenced by the condition of either ACL bundle than the IR (Table 3).

4. Discussion

The main idea of the presented study was to indicate the role of the AM and PL bundles of the ACL in the kinematic changes of the knee joint, especially in the rotational stability. The role of the ACL in kinematics of the knee joint has been studied in several research studies. These studies were carried out in experimental conditions [18–20], after cutting the ACL partially or totally [18–20,25], after reconstruction of the ACL in a cadaver [26] or after reconstruction of the ACL intraoperatively in a patient [21–24]. Monaco et al. [18] presented a study in 2011 that is the most comparable one to our research. Their paper describes the rotational and anterior–posterior stability of the knee joint while using a navigation system. The authors evaluated the kinematics in ACL-intact knees, after cutting PL-bundle of the ACL and in ACL-deficient knees. As for rotational stability, they concluded a minimal increase in IR and ER after cutting the PL bundle of ACL (without statistical significance). In our research, both IR and ER increased after a part of the ACL was cut, although this increase was without statistical significance, but cutting both bundles of the ACL was done at random. Therefore, the role of each bundle was studied separately. After cutting the AM bundle, both rotations increased more than after cutting the PL one. The instability of the knee in rotational movement was higher after cutting both bundles of the ACL. Our results disprove the premises of many authors, who claim that the PL bundle restores the knee stability in IR more than the AM bundle [23,24].