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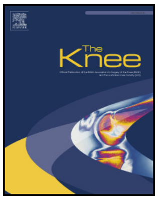

Anatomical features of tibia and femur: Influence on laxity in the anterior cruciate ligament deficient knee

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ABSTRACT

Background: Until now, there has been a lack of in vivo analysis of the correlation between bony morphological features and laxity values after an anterior cruciate ligament (ACL) injury.
Methods: Forty-two patients who underwent ACL-reconstruction were enrolled. Static laxity was evaluated as: antero-posterior displacement and internal–external rotation at 30° and 90° of flexion (AP30, AP90, IE30, IE90) and varus–valgus rotation at 0° and 30° of flexion (VV0, VV30). The pivot-shift (PS) test defined the dynamic laxity. Using magnetic resonance imaging, we evaluated the transepicondylar distance (TE), the width of the lateral and medial femoral condyles (LFCw and MFCw) and tibial plateau (LTPw and MTPw), the notch width index (NWI) and the ratio of width and height of the femoral notch (N-ratio), the ratio between the height and depth of the lateral and medial femoral condyle (LFC-ratio and MFC-ratio), the lateral and medial posterior tibial slopes (LTPs and MTPs) and the anterior subluxation of the lateral and medial tibial plateau with respect to the femoral condyle (LTPsublx and MTPsublx).
Results: Concerning the AP30, LTPs ($P = 0.047$) and MTPsublx ($P = 0.039$) were shown to be independent predictors while for the AP90 only LTPs ($P = 0.049$) was an independent predictor. The LTPs ($P = 0.039$) was shown to be an independent predictor for IE90 laxity, while for the VV0 test it was identified as the LFCw ($P = 0.007$).
Conclusions: A higher antero-posterior laxity at 30° and 90° of flexion was found in those with a lateral tibial slope <5.5°.

1. Introduction

An anterior cruciate ligament (ACL) injury produces instability and altered knee kinematics. While several patients experience an instability that limits their daily life activities, others are able to maintain their preinjury activity levels [1–4]. Several factors might affect the amount of instability experienced by patients; these include the status of other soft-tissues, neuromuscular features of the patient and anatomical characteristics of the joint [1,4–8]. In a previous navigated study by the same author [9], patients presenting higher preoperative laxity values were noted to maintain higher laxity even after reconstruction. According

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to these findings, the role of other misdiagnosed lesions to other stabilizing structures was suggested as a possible explanation for this residual postoperative laxity.

On the other hand, morphological parameters such as the amount of posterior tibial plateau slope and the size of the intercondylar notch have been reported to be associated with higher incidence of ACL tear and were also suggested to increase the risk of post-reconstruction failure [10–13]. Therefore, differences in bony morphological parameters might be responsible for higher preoperative laxity values in the setting of an isolated ACL injury. Several parameters have been investigated in the literature, especially concerning the tibia in both in vitro and in vivo studies [10,14–19]. However, there was a lack of an objective and comprehensive in vivo analysis of the correlation between bony morphological features of a joint and laxity values after an isolated ACL tear.

Therefore, the authors performed a kinematic evaluation of knees with isolated ACL injuries using a navigation system in order to answer the following questions: (1) what is the correlation between the morphological parameter of the knee joint and the static and dynamic laxity values after an isolated ACL injury? (2) Is there any parameter that can be considered as a specific risk factor for high preoperative laxity values in a patient suffering an isolated ACL tear?

2. Materials and methods

All of the consecutive patients operated on by a single surgeon (X.X.) at the Istituto Ortopedico Rizzoli – Clinica Ortopedica e Traumatologica II, who underwent ACL reconstruction and intraoperative kinematic evaluation with a navigation system between 2013 and 2016 were considered potentially eligible for inclusion in the present study.

In order to have a homogeneous group of patients with regard to demographic characteristics, meniscal status and bone morphology, thus minimizing confounding factors, patients were included if they met the following inclusion criteria: (1) age 16–50 years; (2) complete traumatic ACL injury; (3) no lateral or medial meniscus tears; (4) no previous knee ligament reconstruction or repair; (5) no concomitant posterior cruciate ligament (PCL), postero lateral corner (PLC), lateral collateral ligament (LCL) or medial collateral ligament (MCL) lesion; and (6) absence of mild or advanced knee osteoarthritis (Kellgren–Lawrence III–IV).

2.1. Kinematic evaluation

In all of the included patients, static and dynamic laxity was evaluated by the same senior surgeon (S.Z.) that performed the ACL reconstruction, with an intraoperative navigation system (BLU-IGS, Orthokey, Lewes, DE, USA) embedded with a user-friendly software for kinematic assessment (KLEE, Orthokey, Lewes, DE, USA). Kinematic acquisition was performed after arthroscopic confirmation of ACL injury.

Quantification of the static laxity was defined during the following clinical test, executed at manual-maximum load: anterior–posterior translation at 30° and 90° of knee flexion (AP30, AP90), internal–external rotation at 30° and 90° of knee flexion (IE30, IE90), and varus–valgus rotation at 0° and 30° of knee flexion (VV0, VV30).

Dynamic laxity was evaluated during pivot-shift (PS). Such a test was executed following the indications of Jakob et al. [20,21]. The evaluated parameters for the dynamic laxity assessment were the area included by the curves of internal/external rotation during knee flexion and extension in the PS test. Definition of anatomical system of reference and set-up for the use of the intraoperative navigation system followed the procedure reported in previous scientific manuscripts [9,22–25]. For both static and dynamic assessment, the motion of the tibia relative to the femur was evaluated according to Grood and Suntay [26].

Kinematic data were then elaborated offline with a MATLAB interface (The MathWorks Inc., Natick, MA, USA). The reliability of the applied testing method has been evaluated in previous in vivo studies [23,27]. In particular, intratester repeatability of about one millimetre for AP30/AP90 test, one degree and two degrees for VV0/VV30 test, and IE30/IE90 test, respectively, was quantified. The repeatability of the manually executed PS test has been analysed in a previous in vivo study [28], showing good results.

2.2. Magnetic resonance imaging evaluation

Knee magnetic resonance imaging (MRI) was performed at the same institution, using the same protocol with the patient in a supine position and the knee maintained extended. A foam pillow under the knee was used to support it in a relaxed and still position [29]. The orientation of sagittal, coronal and axial planes was defined after the acquisition of two-dimensional scout images. The coronal plane was oriented parallel to the line tangent to posterior condyles, the sagittal plane was oriented parallel to a line passing through the deepest point of trochlea and intercondylar notch, while the axial plane was perpendicular to the previous planes. An expert orthopaedic surgeon, who was blinded to the patients' medical history and laxity values performed the anatomical measurement using the DICOM viewer Osirix Lite 7.0.3 (Pixmeo, Switzerland). For five different patients, the observer performed the measurement twice to assess intra-observer repeatability. MRI measurements were also performed both in the axial, sagittal and coronal planes. In particular, along the axial plane of the femur, the transepicondylar distance (TE) was evaluated.

Along the coronal view the width of the lateral and medial femoral condyles (LFCw and MFCw) and tibial plateau (LTPw and MTPw), the notch width index (NWI) and the ratio of width and height of the femoral notch (N-ratio) were measured.

Along the sagittal plane, the ratio between the height and depth of the lateral and medial femoral condyle (LFC-ratio and MFC-ratio), the lateral and medial posterior tibial slopes (LTPs and MTPs) and the anterior subluxation of the lateral and medial tibial plateau with respect to the femoral condyles (LTPsublx and MTPsublx) were measured.

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