INFLUENCE OF MUSCLE ACTIVITY ON MENISCAL AND FEMORAL TRANSLATION IN PATIENTS WITH DEFICIENCY OF THE ANTERIOR CRUCIATE LIGAMENT

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Introduction: Acute and chronic deficiency of the anterior cruciate ligament (ACL) has been described to be a relevant cause for instability of the knee joint, often leading to secondary changes of the menisci or the cartilage. Investigations about the relevance of the different passive stabilizers has mainly been based on in-vitro studies, dealing with the problem of unknown muscle force relationships [1,2]. For assessing translation in-vivo, conventional radiography is only of limited value, because it is restricted to two planes and can only visualize the bony components. Magnetic resonance imaging (MRI), on the other hand, is able to also visualize the menisci and the cruciate ligaments, because of its excellent soft tissue contrast. Recently, it has been shown that, by using an open MR system, joints can be assessed in functional important positions and in particular under the influence of isometric muscle activity [3, 4], allowing to analyze the relevance of neuromuscular control mechanisms on joint stability. The objective of this study was thus to apply an open MR imaging and 3D postprocessing technique 1) to measure 3D translation of the femoral condyles and the meniscus in different flexion angles during isometric activity of the flexing and extending muscles in patients with deficiency of the ACL and 2) to compare these values to the healthy contralateral side.

Material and method: Both knee joints of 9 patients (age: 18-35) with an unilateral ACL insufficiency were examined in an open MR scanner (0.2 T; Magnetom Open, Siemens, Germany). Three patients showed acute and 6 chronic deficiency, there were no meniscal tears. The contralateral, unaffected knee showed no signs of degeneration and had no history of trauma. For image acquisition, a T1-weighted 3D gradient echo sequence (TR 16.1 ms, TE 9.0 ms; FA 25°) with a spatial resolution of 1.88 x 1.56 x 0.86 mm³ and an imaging time of 4.26 min was used. First, the healthy knee was examined at 2 different flexion angles (30° and 90°) in a neutral rotation position, controlling flexion and rotation with a specific positioning device. For the activation of the extensor or flexor muscles, a 3 kg weight with a flexing or extending force direction was applied perpendicular to the distal tibia. The same assessment was then performed at the injured knee. After data transfer to a multiprocessing computer (Octane Duo, SGI), semiautomatic segmentation and 3D reconstruction of the femur, the tibia, the medial and lateral menisci, and the anterior and posterior cruciate ligament were performed. For determining the 3D translation of the knee, the midpoint of the medial and lateral plateau was determined for each side separately. The posterior border of the femoral condyles and of the menisci were then marked interactively. The minimal spatial distance between the midpoints of each tibia plateau and the axes of the femur condyles and of the menisci were determined. Finally, the differences between extending and flexing muscle activity were calculated for each joint position and compared between the injured and unaffected knee.

Results: During flexion of the knee, posterior translation of the menisci was found, ranging from 0.7 ± 2.1 mm (lateral meniscus) to 3.4 ± 2.7 mm (medial meniscus) in both, the healthy as well as in the affected knee. Comparing extending and flexing muscle activity, anterior translation between 0.2 ± 1.5 mm (lat. meniscus) and 1.3 ± 1.3 mm (lat. condyle)(Tab. 1) was measured during extending activity at 30° flexion angle. At 90°, on the other hand, a posterior translation of the medial condyle (0.5 ± 1.1 mm) and the lateral med. meniscus (0.7 ± 1.0 mm) could be observed during extending activity. For the lat. meniscus (0.4 ± 0.9 mm) and the lat. condyle (0.7 ± 1.5 mm), however, the direction was anterior (Tab. 1). In the injured knee, anterior translation of the med. condyle was significantly increased (injured: 2.2 ± 1.4 mm; healthy: 1.0 ± 1.7; p<0.05) when comparing extending to flexing muscle activity at 30° flexion angle (Tab. 1), while the med. meniscus showed no significant differences (1.0 ± 2.6 mm vs. 0.8 ± 1.8 mm; p = n.s.). In the lateral compartment, no obvious differences between healthy and injured knees were observed (Tab. 1). At 90° flexion angle, the affected knee showed a slight posterior translation during extending muscle activity for both menisci in the patients (lat.: 0.8 ± 1.7 mm; med.: 0.1 ± 0.7 mm), compared with extending muscle activity. No significant differences between the healthy and the affected knee are observed at 90° of knee flexion.

Discussion: In this study, we demonstrate that 3D translation of the menisci and the femoral condyles can be assessed quantitatively and under individual neuromuscular control, using an open MR system and specific postprocessing techniques. The relevance of the active stabilizers can be quantified in different joint positions, demonstrating posterior translation of the menisci during knee flexion from 30° to 90°. Comparing the influence of flexing and extending muscle activity on joint translation we find that at 30° of flexion - under extending muscle activity – an anterior translation of the femoral condyles is observed, both in the healthy and in the affected knee. However, these differences are only small (between 0-1 mm) in healthy side and significantly higher (between 0.5 and 2.2 mm) in the affected knee. In contrast, the difference for the medial meniscus was low. The different translation pattern of the femoral condyles and the meniscus at 30° of flexion may cause higher shear stresses between both components in the patients and may finally be responsible for secondary meniscal tears. At the lateral compartment, no significant difference between the translation pattern of the condyles and the meniscus was observed, corresponding to the clinical finding that usually the medial (and only rarely the lateral) meniscus is affected from secondary damage. We observed that some injured knees showed only small differences to the healthy side, while others demonstrated an enormous amount of translation, suggesting that some patients can better compensate ACL insufficiency by their active stabilizers, while in others this neuromuscular control mechanism appears to fail. These findings suggest that there is a specific subset of patients which is able to compensate insufficiency of the ACL by the muscles, whereas others are not. A potential application of this technique is to identify patients that require surgical stabilization and to successfully discriminate these from other subsets of patients that should be treated conservatively.


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