Mapping isometry and length changes in ligament reconstructions of the knee

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SUMMARY

This thesis offers an overview of the length changes and isometry of the most frequently performed ligament reconstructions of the knee joint. The primary goal of this thesis was to improve our knowledge about the complex function of the anatomical ligaments of the knee. This newly gathered knowledge could improve the contemporary ligament reconstructions of the knee to reduce the amount of failed grafts related to tunnel malpositioning.

To study the length changes and isometry of the ligaments of the knee, we used a non-invasive imaging methodology to capture the in vivo biomechanics. Dual fluoroscopy was used to capture the in vivo joint motion and was combined with magnetic resonance (MR) or computed tomography (CT) imaging which were used to reconstruct the bony anatomy of the knee. To overcome the knee-to-knee differences, a quadrant method was used to apply the anatomical attachments of the ligaments to the 3-dimensional knee models.

In ***Chapter 2***, we show the length changes of the center of the anatomical anterior cruciate ligament (ACL) and the "over-the-top" position. Additionally, we show the isometry of several locations on the medial aspect of the lateral femoral condyle to the ACL attachment on the tibia. The most isometric tibiofemoral combination was found distal and anterior, outside of the anatomical ACL attachment area on the femur. We found that the anatomical ACL was anisometric and was tight at extension, and slackens during deeper knee flexion angles. Due to the impaired kinematics in patients with an ACL tear, i.e., the increased anterior tibial translation and internal rotatory laxity, the distance of the femur to the tibia measured from the ACL attachments significantly increases between 0° to 30° of flexion (***Chapter 3***).

In ***Chapter 4*** we show the length changes of the posterior cruciate ligament (PCL) and the isometry of the lateral aspect of the medial femoral condyle to the tibial attachment of the PCL. The anterolateral bundle of the PCL is slack at extension and tightens gradually during knee flexion. The posteromedial bundle is tight at extension, then slackens till 60° of flexion and tightens thereafter. The most isometric location was found proximal to, just outside, the femoral anatomic footprint of the PCL.

Approximately 25% of the patients that undergo an ACL reconstruction have persistent postoperative knee laxity. This excessive laxity exists primarily in the internal rotation direction with the knee in extension and early flexion ranges. Because of the trajectory of the anterolateral ligament (ALL), it is thought that simultaneous reconstruction of the ACL and ALL may overcome this frequently seen persistent postoperative laxity. In ***Chapter 5*** we show that the anatomic ALL with its attachment slightly anterior and distal to the lateral femoral epicondyle was anisometric and progressively increased in length (i.e. tightened) up to approximately 40% between 0° to 90° of flexion. This length increase makes an anatomic ALL reconstruction biomechanically unfavorable as it will fail. Specifically, the

anatomic ALL would be slack in extension and during early knee flexion and becomes increasingly tight at deeper knee flexion. Thus, the ALL is slack where it is intended to correct the excessive rotational laxity and will be too tight during flexion potentially harming the lateral compartment due to overconstraint.

Although the anatomic ALL reconstruction is unable to resolve the persistent postoperative excessive internal rotation, from a biomechanical point of view, it makes sense to solve any rotational abnormalities at a point further away from the center of rotation (the ACL). Thus, a non-anatomical lateral extra-articular tenodesis (LET) that is able to provide stability at extension and early knee flexion stays interesting. Therefore, in ***Chapter 6***, we show the isometry of several locations on the lateral aspect of the lateral femoral condyle connected to the anatomic attachment of the ALL on the tibia and Gerdy's tubercle. In this study, we were interested to see whether an area existed that yielded favorable length change patterns for an LET. Such area was found posterior and proximal to the lateral femoral epicondyle for both the anatomic tibial attachment of the ALL and Gerdy's tubercle.

Lastly, in ***Chapter*** *7*, we studied the length changes of the medial patellofemoral ligament (MPFL) and the isometry of the medial aspect of the medial femoral condyle to the patellar MPFL attachment. The anatomical MPFL is tight in extension and slackens till approximately 30° of flexion and stays near isometric thereafter. The MPFL allows the patella to smoothly enter the trochlea and prevents the patella from dislocating laterally at deeper flexion angles. The most isometric location was found posterior and proximal to the anatomical femoral footprint of the MPFL close to the adductor tubercle.