Estimation Of Ligament Strains In A Cadaveric Knee Model- Conventional ACL Reconstruction Vs Lateral Augmentation

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Background

Of the several ligaments in the knee joint, the Anterior Cruciate Ligament (ACL) has the highest rate of injury during dynamic activities. Anterolateral ligament injuries frequently occur at the same time as an ACL injury and can lead to residual rotational laxity. Isolated ACL Reconstruction (ACLR) have been shown to have limited restoration to intact knee kinematics, with evidence suggesting that an anterolateral procedure in combination with an ACLR may provide better results to restore native knee kinematics but it is unclear how the anterolateral procedure might be optimised in order to achieve the best patient outcome.

Objectives

This study aims to compare the strain levels of knee ligaments following ACLR with and without an anterolateral procedure. By simulating knee motion as observed during surgery, we can calculate ligament strains in different ligaments under different surgical reconstructions and identify scenarios which are potentially high risk. Furthermore, successfully determining the strains is an important first step in creating a computational model for preplanning and optimising ACLR procedures.

Study Design & Methods

A fresh-frozen male cadaver lower body was used to create a subject-specific musculoskeletal (OpenSim) model. Knee kinematics were acquired using a 3D motion capturing system for three cycles of passive knee flexion from 0-120° with an applied 5Nm of internal rotation (IR) torque to the tibia. Two groups were considered: 1) ACLR and 2) ACLR combined with anterolateral ligament

reconstruction (ALLR). 3D specimen specific bone and cartilage geometries were created through segmentation of CT and MR images. Ligament attachment positions, joint centres and bony landmarks were calculated. A 6DOF knee model was created with seven ligament bundles including: anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), superficial medial collateral ligament (SMCL), deep medial collateral ligament (DMCL), lateral collateral ligament (LCL), popliteofibular ligament (POPL) and anterolateral ligament (ALL). Kinematics and torque were applied to the model as per the experiment to obtain ligament force values. Ligament strains were calculated based on stress-strain relationship of the predefined ligament model and validated with previously published studies.

Results

The ALLR technique resulted in significantly smaller strain values in ACL (12%), PCL (23%) and DMCL (19%) at 30 and 45 degrees of knee flexion ($p \leq 0.007$) compared to strains following
ACLR surgical approach. No significant changes were observed in strain values of the SMCL, LCL, POPL and ALL ligaments between two surgical techniques ($p>0.05$). Also, when comparing the ACLR vs ALLR knee, the DMCL and POPL, showed the most deviation from the intact strains, at 29.7˚ and 35.6˚ of knee flexion for ACLR and ALLR, respectively.

Conclusions

This is the first study to estimate the strains in all knee ligaments based on passive knee kinematics using OpenSim modelling techniques. These findings indicate that ALLR surgical approach can reduce the strain levels within the ACL, PCL and DMCL ligaments compared to strains in the conventional ACLR technique. This supports evidence that the ALLR surgical technique improves kinematics of the knee immediately post-surgery and may improve patient outcomes in the longer-term. This study also shows that musculoskeletal modelling can be used
to accurately replicate experimental conditions and is considered the first step in the development of a surgical planning tool for optimising ACLR procedures, such as tunnel placement and graft type, for improved patient outcomes.