

Optimal Graft Selection for Combined ACL-PCL Reconstruction Using Finite Element Analysis on Ligament Strain, Chondral and Meniscal Loads

Corey J. Scholes, PhD, AUSTRALIA
Samuel Grasso, B.Eng. (Mechanical), AUSTRALIA
Brett A. Fritsch, MBBS BSc(Med), AUSTRALIA
Joe Lynch, AUSTRALIA
Qing Li, PhD, AUSTRALIA
Richard Smith, PhD, AUSTRALIA
David Anthony Parker, MBBS, BMedSci, FRACS, AUSTRALIA

Sydney Orthopaedic Research Institute
Sydney, NSW, AUSTRALIA

Summary:

Finite element analysis reveals that a certain combination of ACL-PCL grafts more closely resemble average loads in the uninjured knee

Abstract:

INTRODUCTION

Reconstruction of the knee affected by rupture of more than one ligament is a challenge for the orthopaedic surgeon. The evidence base for a number of factors important to the surgical process is lacking. While optimal biomechanics are important for knee function and longevity, decisions such as graft selection are often based on surgeon experience and material availability rather than their biomechanical implications. To address this gap in the knowledge, the purpose of this study was to examine the effect of graft material properties on soft tissue loading in a multiple-ligament injury.

METHODS

A simulated ACL-PCL reconstruction was generated using a combination of computer assisted design and finite element analysis (FEA). A geometric knee model was created from the MRI of a healthy male subject using manual image segmentation. The ligaments were represented as hyper-elastic structures, while the menisci and articular cartilage were represented as discrete elements. The material properties of the ACL and PCL were then manipulated based on literature values corresponding to commonly used grafts for reconstructing these ligaments. The graft options analysed were quadrupled semitendinosus autograft, tibialis anterior allograft and Achilles tendon allograft. Partial meniscectomy was also simulated within the model by subtracting part of the volume of the posterior horn of either the lateral or medial meniscus. The model was then loaded using data derived from gait analysis of the subject in a motion capture laboratory. The resulting stress and contact pressures for the ligaments, menisci and cartilage were compared between different graft combinations with and without medial and lateral partial meniscectomy.

RESULTS

The combination of semitendinosus autograft for the ACL and Achilles tendon allograft for the PCL best mimicked the soft-tissue average stress in the healthy condition, with or without partial meniscectomy. Qualitative analysis suggests that the contact area, particularly on the femoral cartilage, is altered by the loss of meniscal tissue in the partial meniscectomy state. With a partial medial meniscectomy the medial femoral cartilage was loaded more medially and posteriorly compared to the healthy condition. With a partial lateral meniscectomy, the area of loading on the medial femoral cartilage was larger and more anterior.

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CONCLUSION

The present study provides the first biomechanical basis for graft selection in multiple-ligament knee reconstruction. The results suggest that mechanics of the knee are not completely restored regardless of the graft combination, but that some combinations better approximate normal conditions than others. This is useful in clinical decision making for these complex reconstructions, and further analysis is required to reveal potential interactions between material properties, graft size and tunnel placement.