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AIMS

- To define the design criteria of an artificial ACL which could reproduce the non-linear load-elongation characteristics of the native ACL.
- To investigate the mechanical behaviour of a novel ACL reconstruction design.

INTRODUCTION

Kinematic and survivorship studies on ACL deficient knees have emphasised the importance of preserving and/or reconstructing the ACL [1]. The unique structure of the ACL enables a non-linear response to force at different flexion angles, this is thought to be a key element in providing normal knee kinematics (Fig 1).

Current synthetic ACL reconstruction grafts have shown poor long-term results, mainly due to wear, creep, fatigue and mechanical failure. None of the synthetic and biological grafts used for the ACL reconstruction have been able to replicate the normal mechanical behaviour of the ACL and prevent degenerative disease progression such as osteoarthritis.

MATERIALS & METHODS

The desired non-linear load-elongation characteristics of the synthetic ACL were defined based upon the in vitro and in vivo characteristics of the native ACL [3]. The design selected for the artificial ACL consisted of a metallic elastic system and a polymeric cord; whether this system could simulate the non-linear behaviour was examined, and mechanical tests were performed to assess the feasibility of long-term implantation. Suitable materials for the ACL reconstruction design (CoCrMo alloy and UHMWPE fibres (Fig 2) were identified based on their biocompatibility, strength, strain, creep and fatigue properties (Fig 3).

Fig 2. Braided construct of UHMWPE fibre [3]

The effect of humidity, temperature and strain rate on the mechanical properties of UHMWPE loops was investigated. Cyclic fatigue tests were performed on UHMWPE loops for up to 6.4 million cycles at 1 Hz under 40-400 N load in simulated body conditions.

In order to investigate whether the system could reproduce the non-linear properties, finite element modelling was used. The accuracy of different plasticity models to predict the UHMWPE loop under cyclic loading were examined to identify the most suitable material modelling approach; the loading-unloading uniaxial cyclic test was virtually simulated on finite element models using ABAQUS software (version 6.9- Simulia; RI, USA).

The prototype ACL design was tested on three cadaver knees; the restoration of joint stability was quantified using a KT1000 arthrometer. The synthetic ACL design was implanted with/and without total knee replacement (TKR). For each knee, anterior tibial translation was measured for; the intact healthy knee without surgical exposure, after ACL removal (ACLR), after ACL reconstruction (ACL-R), after TKR (ACLTKR), and after TKR with reconstruction (ACLTKR).

CONCLUSIONS

- The non-linear force-elongation properties of the native ACL could potentially be reproduced by an artificial ACL reconstruction system in the ACL-deficient knees.
- A non-linear isotropic kinematic hardening model predicted the cyclic behavior of UHMWPE fiber construct to within 24%.

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