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ACL PRESERVING TOTAL KNEE REPLACEMENT CAN IMPROVE KNEE STABILITY

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SUMMARY
Two prototype bi-cruciate retaining total knee arthroplasties (TKAs) were tested using cadaver specimens in the laboratory. Results and experiences from testing the first prototype were used to inform the second design. Results were promising, with anterior kneelaxity reducing (moving towards normal) with either the native ACL present, or with a synthetic ACL when compared to a conventional ACL-resecting TKA. Further work is being completed on implant and instrumentation design and more cadaver testing will be carried out as further proof of concept and function.

INTRODUCTION
Total knee arthroplasty (TKA) is a successful treatment for arthritis of the knee, eliminating pain and typically having a long term survivorship rate of greater than 90%. Success of implants is measured by survivorship rate, with revision of the TKA being regarded as the failure point. Eight year survivorship of TKAs reported by the National Joint Registry in the United Kingdom in 2012 was 97% [1]. Despite these good clinical outcomes, dissatisfaction rates among patients can be as high as 20% [2-4]. Even the newest TKA designs do not restore joint function to pre-disease levels, therefore limiting the post-operative activities that patients can perform and contributing to this level of dissatisfaction. The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are known to control knee stability and tibiofemoral kinematics. The removal of the ACL where a cruciate retaining (CR) prosthesis is implanted or both ACL and PCL where a posterior stabilised (PS) prosthesis is implanted is believed to be partially responsible for the loss of joint function. The combined ligament function is not adequately mimicked by conventional TKAs, causing instability and an unnatural feeling in the replaced knee which can result in reduced patient confidence, mobility and function. There is in vivo evidence that a bi-cruciate retaining TKA can improve replaced knee motion and corresponding patient satisfaction [5-10]. However, these devices have never been mechanically evaluated or used clinically beyond the realms of their surgeon-inventors. The aim of this study was to assess the surgical feasibility and mechanical performance of a novel TKA which retains the ACL in cases where the ligament is not too severely diseased, and incorporates an ACL reconstruction in cases where the native ACL is not viable. A cadaver study was performed with a prototype design and instrumentation to compare the tibiofemoral kinematics and stability of knees in 4 states: intact; ACL and PCL preserving TKA; conventional TKA (ACL sacrificed); and a PCL preserving TKA with a synthetic ACL. Design modifications were made to the implant and a second round of cadaver testing was conducted.

METHODS
Thirteen fresh-frozen cadaver specimens (8 male, 5 female; mean age 80.7 years; range 55-91 years) from consented donations were obtained from the International Institute for the Advancement of Medicine (Jessup, Pennsylvania, USA) and ethical permission for the study was granted by the National Research Ethics Service. Nine knees were used in the first study; the remaining 4 were used to test the updated design. Two separate cadaveric experiments were conducted to compare an ACL-sacrificing, PCL-preserving conventional TKA with two versions of a bi-cruciate retaining TKA. All 3 TKA designs used the same femoral component (Unity TKA, Corin, UK), but had different tibial trays and UHMWPE bearings. A previously developed test method and bespoke kinematics testing rig were used for this study [11-13]. The intact knee was initially tested with only a 400 N central quadriceps force and then with the following loads applied in conjunction with the quadriceps: (1) 135 N tibial anterior drawer force; (2) 135 N tibial posterior drawer force; (3) 7.5 Nm tibial internal rotation torque and (4) 7.5 Nm tibial external rotation torque. In each loading condition, the knee was moved manually over 3 cycles of knee flexion-extension between 0° and 110°. When the intact measurements were complete, the TKA was implanted. The test regime was then repeated with the knee in 3 further states: (1) TKA with intact ACL; (2) CR TKA with resected ACL and (3) CR TKA with synthetic ACL. The loads and torques described here were 50% greater than those used in previous work in order to amplify any differences between the knee states.

Tibiofemoral motions were recorded using the Polaris optical tracking system (NDI, Waterloo, Canada) and the data was processed with Visual3D (C-Motion, Maryland, USA).

RESULTS AND DISCUSSION

In the first round of cadaver testing, the surgical feasibility of implanting firstly an ACL-retaining CR TKA and secondly incorporating this TKA with a reconstructed ACL was proven. It was also shown that anterior laxity (the difference in tibial translation between neutral loading and the anterior drawer case) was more closely mimicked with the ACL-retaining TKA and the synthetic ACL TKA, than with the conventional TKA (Figure 1). An overall significant increase was found for the anterior laxity with the conventional TKA versus the intact knee (P=0.004). It was noted however, with this prototype design of the ACL-retaining TKA that avulsion fracture of the remaining tibial spine was a recurring problem particularly near full extension of the knee. Fracture took place in 6 out of 9 knees (67%) and as a consequence, data was only collected for all 9 knees in all 4 states for angles of flexion between 20° and 95°.

For the second round of testing, the metal tibial tray and UHMWPE inserts were both redesigned with a view to addressing the aforementioned fracture problem. For the 4 knees that were tested, only 1 experienced a fracture and in the remaining three knees the, ACL-retaining TKA exhibited similar anterior laxity levels to that of the intact knee.

The concept of a bi-cruciate retaining TKR (either with the native or synthetic ACL) was tested in the first cadaver session and was shown to be a valid approach to restoring pre-osteoarthritic knee stability. However, during this session it became apparent that the bi-cruciate retaining TKR design was altering the native ACL forces and causing the bony eminence on the tibia to fracture in extension. In an attempt to address this phenomenon, a newly designed tibial plate was manufactured and tested in the second cadaver session. Results for the new design were encouraging, it was easier to insert and there were fewer problems with balancing the knee which led to fewer fractures. Further work is now being carried out on the tibial tray and instrumentation to ensure that the knee is properly balanced in flexion and extension and to allow the most natural function in terms of knee kinematics and ligament tensions.

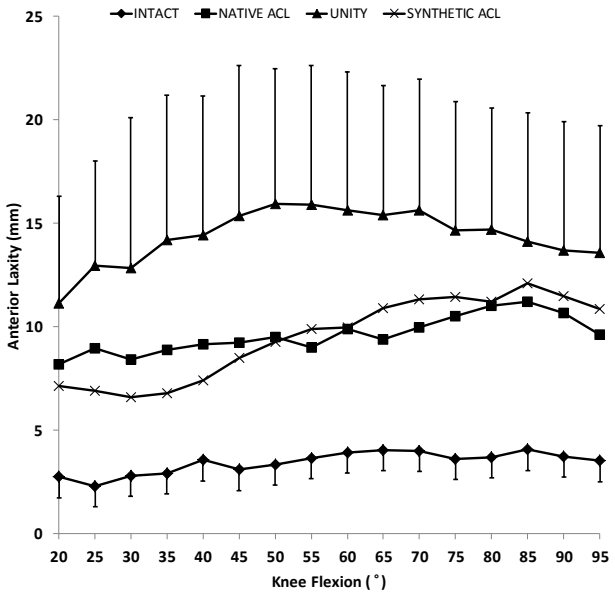

Figure 1: Mean anterior laxity for 9 knees. Error bars are 1 standard deviation.

CONCLUSIONS

Bi-cruciate total knee arthroplasty is surgically feasible and could improve post-operative knee laxity and kinematics thereby increasing patient function and satisfaction levels.

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