EFFECTS OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION USING PATELLA TENDON BONE GRAFT ON IN VIVO TENDON MECHANICAL PROPERTIES

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SUMMARY
The purpose of this study was to examine the recovery of patellar tendon mechanical properties, stiffness and joint function following anterior cruciate ligament surgery using a patellar tendon graft. The work also examined the effect of imaging the whole tendon using ultrasound as opposed to the proximal portion only on the calculation of tendon mechanical properties. Eight participants who had undergone ACL reconstruction using a patellar tendon bone graft and were between 5 and 10 years post surgery were selected. The uninjured knee served as control. The patellar tendon mechanical properties were assessed in vivo using both dynamometry and ultrasound imaging. The stiffness of the tendon was similar between sides despite a lower Young’s modulus indicating inferior material properties in the operated tendon. This was probably due to the compensatory increase in the tendon cross sectional area. The imaging method by visualizing the entire tendon with a long ultrasound probe or only its proximal portion had no effect on the operated vs control side comparisons. The overall results showed a recovery of the knee extensor muscle–tendon unit after graft procurement from the patellar tendon for ACL reconstruction.

INTRODUCTION
Early surgical reconstruction of the torn anterior cruciate ligament (ACL) is widely performed in order to alleviate the associated symptoms and progressive knee deterioration. One of the most common grafts used for ACL reconstruction is the central third or the medial third of the patellar tendon. The graft site for the reconstruction is either the central third or the medial third of the patellar tendon. In Vitro studies on animal tendon have shown that removal of the central third of the tendon cause a significant reduction in the stiffness and ultimate load to failure of the remaining tendon for up to 6 months post surgery. This poor tensile quality of the remaining tendon raises concerns whether a decrease in the knee extensor strength could be partly due to graft site morbidity caused during graft procurement from the healthy patellar tendon. However, recent in vivo, ultrasound-based studies have shown that the human patellar tendon adapts to experimentally controlled mechanical loading by altering its mechanical properties [for review see 1]. It has also been documented that the stiffness of the human patellar tendon is restored after graft harvesting for ACL reconstruction [2]. In this previous study we found a significantly larger anterior laxity in operated compared to control knees [2]. This challenges the assumption that the distal patellar tendon attachment does not move on a local scan taken during a ramp intensity isometric knee extension required to assess the tendon properties in vivo, or at least it moves similarly between conditions when imaging only the proximal portion of the patellar tendon. A differential shift in the distal attachment of the patellar tendon between operated and control conditions may yield a different outcome with respect to the restoration of tendon stiffness following ACL surgery dependent upon the method of imaging. The present study therefore tests this hypothesis by imaging the whole tendon and also considering analysis incorporating on the proximal portion of the tendon and considering the implications of this methodological issue upon the recovery of tendon stiffness following ACL surgery using the patellar tendon graft.

METHODS
Eight participants were selected who had undergone ACL reconstruction using the patellar tendon bone graft (5 males and 3 females; 38.4±13.8 years, 77.1±9.6 kg and 1.72±0.06 m). All participants were between 5 and 10 years post surgery and the uninjured knee served as control. The patellar tendon mechanical properties were assessed in vivo using both dynamometry and ultrasound (US) imaging. Knee extensor torque during maximum voluntary contraction (MVC) and internal moment arm affecting the joint were also assessed. Patellar tendon stiffness was calculated from the gradient of the tendons force-elongation curve. Tendon stiffness was normalized to the tendon dimensions (length and cross sectional area) to obtain the Young’s modulus. This study also had several methodological advantages over previous work. In order to obtain patella tendon mechanical properties the full tendon was imaged with a specially constructed long ultrasound probe (10 cm) that enabled measurement of elongation while visualising both proximal and distal attachments of the tendon (Figure 1). In a second data set, the analysis was also conducted by assuming that we could only view the displacement of the proximal portion of the patellar tendon. These two different experimental approaches were compared against each other and in terms of their impact upon measuring the recovery of tendon stiffness following the surgical intervention. Tendon cross sectional area was estimated from axial plane MRI scans which clearly demarcated the tendon borders.
RESULTS AND DISCUSSION

The cross sectional area of the operated patellar tendon was 36% larger than that of the uninjured control tendon. Firstly, patella tendon stiffness was not significantly different between the operated the uninjured control tendons, but the Young’s modulus was significantly lower by 25% when compared to the control tendon (Figure 2). These results indicate that even though the material properties of the operated tendon were inferior (reflected in the significantly lower Young’s Modulus) the stiffness was similar between sides. This is probably due to the greatly increased tendon cross sectional area of the harvested tendon, which presumably compensates for the deterioration in material properties. Regardless of whether the whole tendon, or only its proximal portion was imagined, the operated vs control tendon comparison was the same, i.e., there was no significant difference in stiffness between conditions, but the modulus was lower in the operated tendons. There was however, an influence of imaging method on the measured elongations, with significantly larger elongations measured when imaging the whole tendon due to a shift in the tendon’s distal attachment, indicating tibial movement in the transition from rest to MVC. These findings are in agreement with our previous observations [2] on the recovery of tendon stiffness following ACL surgery using the patellar tendon graft. In terms of methodological assumptions, it seems that although there is a shift in the distal tendon attachment with respect to the scan due to tibial movement, this is similar for the operated and control legs, resulting in the same conclusions being reached regardless of imaging method.

CONCLUSIONS

The results clearly demonstrated a recovery of the knee extensor muscle–tendon unit after graft procurement from the patellar tendon for ACL reconstruction. The stiffness of the tendon was similar between sides due to the compensatory increase in the tendon cross sectional area. Therefore, the results of the present study are promising to both the surgeon involved with ACL reconstruction and patients undergoing the procedure using the patellar tendon bone graft. In terms of imaging method, visualizing the entire tendon or only its proximal portion had no effect on the operated vs control comparisons. There were, however, larger elongations measured when visualizing the whole tendon, compared to just the proximal portion.

REFERENCES