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Influence of graft location on primary stability of osteochondral grafts implanted into cadaveric human knee joint

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Blake McCall , Raelene M Cowie and Louise M Jennings

Institute of Medical and Biological Engineering, School of Mechanical Engineering, University of Leeds, Leeds, LS2 9JT

Disclosures: Blake McCall (None), Raelene M. Cowie (6 – Invibio, MatOrtho), Louise M Jennings (5 – Mathys, DePuy Synthes, Invibio, MatOrtho)

email: l.m.jennings@leeds.ac.uk

Introduction

Osteochondral grafts are used clinically as a treatment for focal cartilage defects of the knee to restore the articulating surfaces of the joint.

The clinical success of osteochondral grafts is heavily reliant on their mechanical stability. In the early postoperative period, prior to integration between the graft and recipient site, graft stability is dependent on the press-fit between the graft and host tissue, this is known as the primary stability.

One method of assessing primary stability is to measure the push-in force required to displace a graft below congruency. Push-in force can be a good indication of the clinical success of the graft, as grafts which protrude above or subside below the native cartilage may have a negative effect on the biomechanical and tribological properties of the joint [1], potentially leading to degenerative changes or the formation of fibrocartilage which is biomechanically inferior to native cartilage [2].

Grafts implanted with a higher push-in force have greater stability so may be less likely to subside in situ however, high push-in forces are associated with high implantation forces. Excessive force applied to graft may lead to cartilage damage and has been associated with a reduce chondrocyte viability [3].

Aim

The aim of the this study was to determine the primary stability of grafts implanted into different locations in the knee joint by measuring the push-in force required to displace a graft below congruency.

Methods

- Nine human cadaveric patellae, six tibias, twelve trochlear grooves and nine femoral condyles from a total of 14 donors were studied.
- In place of autografts, surrogate grafts with a diameter of 8.7mm and length of 8mm were manufactured from Delrin® to maintain the graft properties consistent between samples. A high modulus material was used to ensure the graft did not deform and measured differences in the push-in force could be attributed to variation in recipient site properties.
- Recipient sites were drilled using an 8.5 mm diameter drill-bit supplied with the Smith & Nephew osteochondral autograft transfer kit (OATs) (Smith and Nephew, MA, USA) to a depth of 8mm and subsequently dilated using a dilation tool of diameter 8.87mm.
- As a measure of primary stability, push-in force was measured by applying a compressive force at a rate of 1mm/min to a maximum displacement of 5mm. A maximum force limit of 2.5 kN was set, as it was considered unlikely that contact pressures exceeding 50 MPa would occur in a natural knee.
- Micro-computated tomography (µCT) scans of three complete knees were taken prior to testing in order to compare bone volume fraction (BV/TV) across the femoral condyles, trochlear groove, tibial plateau and patella (XtremeCT, Scanco Medical AG, Switzerland; 82 µm isotropic voxel size: 900 IA, 60 kVp energy and 300 ms exposure).

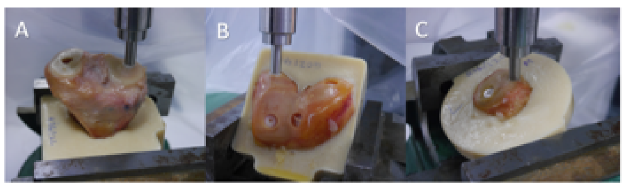

Figure 1: Samples mounted to Instron 3365 and push-in test being performed on (A) Medial and Lateral Tibial Plateau, (B) femoral condyles and trochlear groove, (C) Medial and Lateral patella.

Results

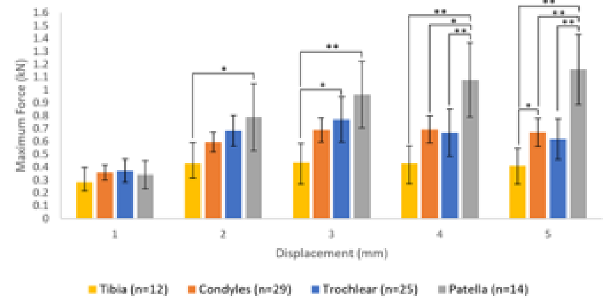

*Figure 2: Mean maximum compressive force required to displace graft below congruency. Tests were stopped at either 2.5 kN force or 5mm displacement. Error bars represent 95% confidence limits. * indicates p<0.05, ** indicates p<0.005.*

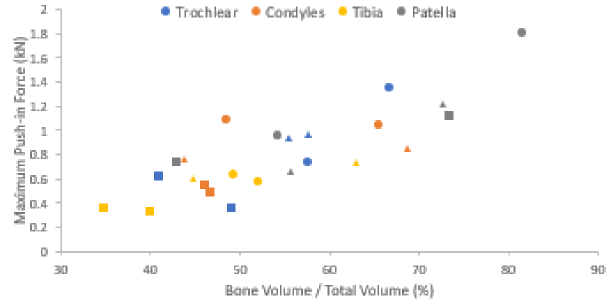

Figure 3: Maximum push-in force ((kN) against Bone volume fraction (%) for grafts implanted into the tibial plateau, trochlear groove, femoral condyles and patellae from three donors. The coefficient of determination for all data points combined $R^2 = 0.66$ (Trochlear $R^2 = 0.66$; Condyles $R^2 = 0.24$; Tibia $R^2 = 0.78$; Patella $R^2 = 0.74$). The 3 knees investigated are represented by a circle, triangle and square.

Discussion

- At small (physiological) displacements (<1.5 mm), the location in which the graft was implanted had no influence on the push-in force; at higher displacements, the push in force in the tibia was significantly lower than the patella and trochlear but at this level of subsidence in a patient, the graft would likely no longer function as intended.
- The µ-CT scans show clear differences in the bone microstructure between the different recipient site regions suggesting a link between bone structure and graft stability. However, there was no significant difference in BV/TV between the different recipient site locations. A positive correlation between bone volume fraction and push-in force was observed, indicating that greater stability occurs when grafts are implanted in higher density bone, consistent with previous studies in porcine bone [4].
- Further work is necessary to understand how grafts or grafting techniques can best be stratified based on the properties of the recipient site and the biomechanics of the joint.

References:

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[3] Quinn, T.M., et al., *JOR*,2001. 19,242-249.

[4] Day, G.A., et al., *Journal of the Mechanical Behavior of Biomedical Materials*, 2022. 134,105411.

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