PARAMETRIC ANALYSIS OF OSTEOCHONDRAL GRAFTS IN HUMAN TIBIOFEMORAL JOINTS

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Introduction

Articular cartilage defects in the knee affect a considerable proportion of the population and range from single focal defects to larger areas of diseased hyaline cartilage. Autologous and allogeneic osteochondral grafting have demonstrated positive outcomes by replacing the damaged region of cartilage with an auto- or allo-graft consisting of a cylinder of bone with a layer of cartilage [1]. However, the factors that affect the short-term stability of the grafts remain largely unknown with some evidence of graft subsidence and poor integration. The aim of this study was to understand the parameters that affect the immediate stability of osteochondral grafts within a tibiofemoral joint using finite element (FE) models. The objectives were to use previously derived and independently experimentally calibrated models to understand the effects of grafting parameters on contact mechanics and graft stability. The effects of graft site dilation, used to prevent damage to grafts upon implantation, was also investigated.

Methods

Previously [2], subject specific FE models of a human tibiofemoral joint were built and validated against experimental contact pressure data for 6 cases with different osteochondral graft conditions (Fig. 1, A). The models contained elementwise material properties of the bone derived from CT scan data with independent validation, and calibrated friction properties between the graft and host bone from an independent study of 12 osteochondral graft push-in tests. This tibiofemoral joint model was used as the foundation for parametric testing of graft properties.

Parametric tests were performed to investigate the effect of changing the density-modulus relationship for the bone component of the graft and the effect of graft site dilation on graft stability. The latter was investigated in two ways, through experimentally validated push-in testing (two knees, 8 total sites, reported previously by McCall et al. [3]) with matching specimen specific FE models, using previously published methodology [4], and through implementing the dilation in the tibiofemoral joint FE model described above. The effect of the grafting parameters was examined by comparing the peak compressive stress, strain and contact pressure. Push-in force comparisons used the force at 1 mm of displacement below flush with surrounding cartilage.

Results

Good agreement was found (CCC=0.86, Fig. 1, B) between models and experimental data when testing the effect of graft site dilation on push-in force, despite no significant difference found between dilated and undilated sites experimentally. Graft bone density and dilation changes had little effect on the resultant tibial contact pressure in the knee joint model (<2% change in peak contact pressure). However, large changes were found internally when measuring peak stress, strain and internal contact pressure on the graft (Fig. 1, C).

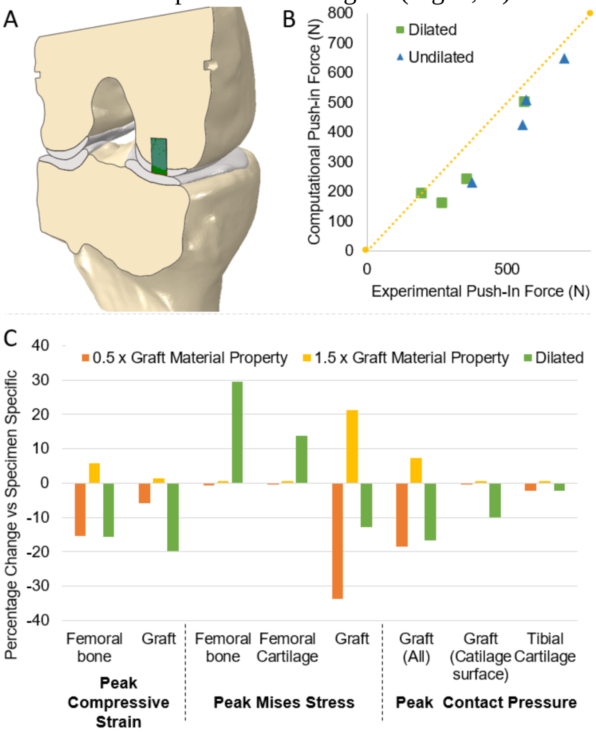

Figure 1: A) An example FE tibiofemoral joint model with an osteochondral graft in the medial condyle. B) Experimental and computational results of push-in testing comparing dilated and undilated graft sites. C) Mean change to metric when using dilated graft site or varied graft bone density.

Discussion

The agreement measured between experimental and computational models including dilation of the graft site continues to add confidence to the modelling approach. Large changes to the stress and strain of internal bone elements when varying properties and site preparation suggests that, clinically, increased care is required when picking autograft site or allograft properties in order to prevent damage to the bone and graft prior to bony integration. Further investigation into the tradeoffs between dilated and undilated graft sites is required given the large changes to stress and strain despite non-significant changes to the push-in force.

References

1. Pareek et al. 2016. Arthroscopy 2. Day et al. ESB 2022
3. McCall et al, ORS 2023 4. Day et al. 2022 JMBBM

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