Introduction: Opening-wedge high tibial osteotomy (HTO) for medial tibiofemoral (TF) osteoarthritis (OA) in varus knees is performed to change alignment and shift load from the diseased compartment in an effort to delay disease progression. Surgeons aim to correct to a specified range of coronal plane alignment, but accurate coronal correction does not guarantee long-term clinical success or improvement in cartilage [1]. One reason may be that HTO affects alignment and kinematics outside of the coronal plane. Statistically significant changes have recently been found in three of five TF kinematic parameters following HTO [2]. The objective of this study was to determine whether there is a relationship between changes in knee kinematics produced by HTO and changes in cartilage GAG content (measured by dGEMRIC).

Methods: Eight male subjects (mean age 50.1 (6.4)) undergoing opening-wedge HTO for medial TF OA had knee kinematics and cartilage health assessed before and after surgery. All subjects gave informed consent and institutional research ethics board approval was granted. TF 3D kinematics [3] and dGEMRIC scores [4] were assessed at three time points (pre-op (PRE), 6-months (6MOS) and 12-months (12MOS) post-op) using a 3T Philips Achieva scanner. One subject (UNCHGD) missed 12MOS scan due to non-union/re-operation. For kinematics assessment, a relaxed, high-resolution scan was obtained, followed by rapid loaded scans at six flexion angles (10°-60°). Bone models (high-res) and pose information (rapid) were registered from manually segmented images (Analyze), and anatomical axes were applied to calculate TF kinematics (MATLAB). For dGEMRIC measurement, an IV double dose (0.2 mmol/kg) of Gd-DTPA2- (Magnevist) was given, followed by 10 min brisk walking. At 90 min post-injection, a saturation recovery series (2D TSE, coronal, 8 TR times) was obtained. Cartilage was segmented and T1 maps were calculated using in-house code (MATLAB). WOMAC scores were obtained at each timepoint. Two groups were defined based on dGEMRIC change: in the DECRES group (n = 3), dGEMRIC score decreased by ≥80 ms PRE to 6MOS (mean -105 ms; recovered: PRE to 12MOS, mean -1 ms); in the UNCHGD group (n = 5), changes were smaller PRE to 6MOS (mean +20 ms; PRE to 12MOS, mean -9 ms). Linear mixed-effects models were used to compare kinematic parameters within each group between timepoints (STATA). T-tests were used to compare between groups (Excel).

Results: In the group with substantially decreased cartilage GAG content at 6 months (DECRES), HTO surgery displaced the tibia anteriorly while in the UNCHNGD group HTO produced no significant difference in anterior tibial translation (Figure 1). In the DECRES group, the tibia was also more proximal over the range of motion after HTO (mean +1.0 mm, p ≤ 0.001) compared to no significant difference in the UNCHGD group (mean +0.35 mm, p ≥ 0.22). Mixed changes were found for other TF parameters. dGEMRIC scores between groups were significantly different at 6MOS (DECRES 486 ms v UNCHGD 625 ms, p < 0.01), but no statistical difference was found at PRE (591 v 605 ms, p = 0.75) or 12MOS (571 v 570 ms, p = 0.98). There was no statistical difference in age (p = 0.29), BMI (p = 0.59), tibial slope change (medial or lateral, 6MOS or 12MOS, p ≥ 0.46) or WOMAC at any timepoint (p ≥ 0.11) between groups.

Discussion: We found statistically significant changes in TF knee kinematics in the DECRES group at 6MOS after HTO, which persisted at 12MOS despite the recovery of TF dGEMRIC values. It is not clear what the 6MOS decrease in dGEMRIC score and subsequent recovery indicates for long-term outcomes; loss and recovery of dGEMRIC score have been observed in a case of PCL rupture [5]. It is also unclear how the kinematic changes associated with changes in dGEMRIC relate to long-term outcomes. Anterior tibial shift may be undesirable due to altered contact centers on the tibia [6], and this change in contact location and/or mechanics may explain apparent changes in cartilage associated with anterior translation. These results provide a starting point for studying the interconnection between knee mechanics changes and cartilage health changes in HTO.

Significance: Changes in 3D TF kinematics and dGEMRIC score appear to be linked in opening-wedge HTO. These changes may be related to clinical success of the procedure, and identifying relationships between joint mechanics and cartilage may lead to improved success of HTO in the future.

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Figure 1: Mean models and data for tibial anterior translation for DECRES (a) and UNCHGD (b). * indicates statistically significant difference from pre-op (p ≤ 0.001).

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