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Paper #35

Opening-Wedge High Tibial Osteotomy Changes 3D Knee Kinematics

Agnes G d'Entremont, MASc, CANADA
Kenard Agbanlog, BASc, CANADA
Simon Horlick, CANADA
Mojieb G. Manzary, CANADA
Trevor Stone, MD, CANADA
Robert G. McCormack, MD, CANADA
David R. Wilson, DPhil, CANADA

University of British Columbia
Vancouver, BC, CANADA

Summary:
Opening-wedge high tibial osteotomy significantly changed 3D knee kinematics at 6 and 12 months, including tibial anterior translation (mean 2.6 mm, $p < 0.001$), patellar distal translation (mean 2.2 mm, $p < 0.001$), patellar spin (mean -1.4 degrees, $p < 0.05$), patellar tilt (mean 2.2 deg, $p < 0.05$), and three other parameters, but did not change patellofemoral dGEMRIC scores ($p > 0.10$).

Abstract:
Introduction:
Medial opening-wedge (OW) high tibial osteotomy (HTO) is a treatment for medial tibiofemoral (TF) osteoarthritis (OA) caused by varus malalignment. This malalignment shifts the line of action of the ground reaction force, which increases load in the medial compartment. This increased load is widely believed to be the cause of medial tibiofemoral OA. HTO restores the line of action to a neutral or slightly lateral position to redistribute load in the TF compartments. Consensus has emerged on an optimal range of angular correction, however achieving this correction does not guarantee good clinical results. Current standard assessment of TF alignment, a standing radiograph, provides a very limited evaluation of joint mechanics, which may explain this discrepancy. Methods developed for assessing 3D knee kinematics in vivo have hitherto seen limited application in HTO, therefore the kinematic changes caused by OW HTO are not well characterized. Following proximal OW HTO (Stoffel 2007), increased patellar contact pressure has been observed, which may affect cartilage health; the dGEMRIC technique allows non-invasive evaluation of cartilage health. Our research questions were: how does OW HTO affect three-dimensional TF and patellofemoral (PF) kinematics? How does PF dGEMRIC score change with HTO?

Methods:
Three-dimensional TF and PF kinematics (Fellows 2005) and PF dGEMRIC cartilage scores were assessed before and after HTO in 13 knees of 12 male subjects (age 48.9 +/- 7.5 years) at three timepoints. Ethics board approval was granted and informed consent was obtained from all subjects. Titanium surgical hardware was used to minimize image artifacts. Some subjects missed follow-up scans for various reasons: at baseline, n = 13; at 6 months, n = 9; and at 12 months, n = 10. dGEMRIC data was unavailable for one baseline and two 12 month scans. For each assessment, the subject lay supine in the MR scanner. A high-resolution T1-weighted mulitslice scan was performed in a relaxed position. Low-resolution images were then obtained at six flexion angles (10°–60°) while the subject loaded his knee using a specially designed rig. Bone was segmented from the MR images and high-resolution bone models were registered to the low-resolution data using an iterative closest points algorithm. Anatomical axes were assigned to each bone using anatomical landmarks. Kinematic parameters (rotations and translations) with respect to femur for both tibia and patella were calculated. dGEMRIC scanning was performed in the same session (double dose of Gd-DTPA2-, single slice axial PF joint). Mixed-level models were used to evaluate the differences in kinematics and dGEMRIC scores between time points. Best statistical models were selected by lowest values of BIC.

Results:

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Changes in kinematics following HTO were seen in both TF and PF joints. HTO caused anterior translation of the tibia (Figure 1) and this was maintained at both post-op timepoints (mean 2.6 mm, $p < 0.001$). HTO also caused distal translation of the patella (Figure 2) and this was maintained at both post-op timepoints (mean 2.2 mm, $p < 0.001$). Statistically significant differences in intercept between baseline and both follow-ups were also found for patellar spin (mean -1.4 degrees, $p < 0.05$), patellar tilt (mean 2.2 deg, $p < 0.05$), patellar lateral translation (mean 0.9 mm, $p < 0.001$), tibial proximal translation (mean -0.5 mm, $p < 0.05$), and tibial lateral translation (mean 0.9 mm, $p < 0.001$). Significant differences were seen in intercept between all three timepoints for tibial adduction (mean between baseline and 6 months, -7.8 deg, $p < 0.001$), and differences were seen in intercept between 6 months and other timepoints for tibial internal rotation (mean -2.2 deg, $p < 0.01$). No significant differences were observed for patellar flexion. The mean T1 value of the PF cartilage showed no significant change between the three time points ($p > 0.10$), with mean T1 values of 664 ms (SD 84 ms) preoperatively, 645 ms (SD 103 ms) after 6 months and 694 ms (SD 77 ms) after 12 months.

Discussion:
Tibial anterior translation after HTO is clinically important because it suggests that the contact centers on the tibia have shifted posteriorly, an undesirable outcome thought to be related to changes in tibial slope (Rodner 2006). In these subjects, the measured anterior translation is not due to a major change in tibial slope: for the majority of subjects, strict protocols were employed to control tibial slope and intraoperative fluoroscopy confirmed that HTO changed tibial slope by less than 3 degrees. Our finding of a distal translation of the patella in OW osteotomy is consistent with radiographic work (Tigani 2001), which found an average 14% distal patellar translation at 30 degrees identical to our result at 30 degrees. Patella infera related to the shortening of the patellar tendon has been problematic in conversion to total knee replacement in closing-wedge osteotomy patients (Westrich 1998). The cause of distal patellar movement in OW osteotomy with internal fixation is likely a geometrical change rather than a change in the tendon (Fan 2012), however it is not clear what effect this will have on conversion to TKA. Our finding that HTO decreased tibial adduction is consistent with the objectives of the surgery because tibial adduction is related to (but not identical to) varus angle as measured on standing-film radiographs. We found that a coronal plane tibial osteotomy has caused a number of PF kinematic changes, including changes not typically examined in radiographic studies. These results were consistent with 3D ex vivo results for spin, tilt, and distal translation (Gaasbeek 2007), It is unclear what clinical affect this may have on the PF joint. Despite kinematic changes in the PF joint, we found no significant difference in PF dGEMRIC score over time. While only one imaging slice was evaluated, this may indicate that the change in kinematics caused by HTO does not affect cartilage health in the PF joint.

Significance:
Three-dimensional kinematic analysis detects changes due to HTO that standard radiographs do not identify, including changes in the PF joint. These changes may be related to clinical success of the procedure, and identifying these relationships may lead to improved success of HTO in the future.