Torsion Deformity and Dynamic Loading for Medial Knee Osteoarthritis

INTRODUCTION:
The consequences of torsion deformity on dynamic loading for knee osteoarthritis (OA) subjects are poorly understood and may include medial compartment overload. Therefore, the purpose of this study was 1) to quantify the effect of torsion deformity on dynamic loading and 2) to assess the imaging correlates of dynamic loading.

METHODS:
Twenty-four subjects were recruited into 3 groups: end-staged medial knee OA subjects with torsion (TKO, n = 6), without torsion (KOA, n = 8, BMI = 33.8 ± 7 kg/m², age = 59 ± 11 yrs.) and controls (CON, n = 10, BMI = 28.4 ± 4 kg/m², age = 62.5 ± 4 yrs.). Torsion deformity was identified from a long standing lower extremity (LSLE) radiograph. The LSLE was used to classify knee OA disease severity for all subjects based on the Kellgren/Lawrence (K/L) scale; knee OA scores were ≥ 3 and controls were < 2.

The mechanical axis alignment for each study limb was measured by two evaluators (KAK and SRR) using the LSLE. Femoral and tibial torsion was assessed by two evaluators (SRR and DSM) using thin slice computed tomography (CT). A partially loaded-limb CT protocol was used to replicate the tibiofemoral joint angle (10° flexion) during the stance phase of gait. Patients were fitted into a torso harness attached to a foot base plate which was loaded with an axial compression force of approximately 55 N. The feet were secured to the base plate in the toe-out angle determined from an ink and paper gait test. Digital LSLE and CT images were archived and measured using a PC workstation.

Dynamic knee loading was determined using level walking motion analysis involving two force plates and eight-cameras. A Newton/Euler inverse dynamic analysis was used to calculate the internal knee varus moment. The 2nd peak knee varus moment (normalized to % body weight * body height) was extracted in addition to the mean stance phase foot progression angle.

Analysis of variance was used to test for between-group differences for the mechanical axis, tibial torsion, knee varus moment and the foot progression angle. A regression model using the imaging measures and the foot progression angle was used to predict dynamic knee loading.

RESULTS:
Medial knee OA subjects, with and without torsion deformity, had significantly greater BMI (P = 0.038) compared to controls. The TKOs had significantly greater mechanical axis varus alignment when compared to KOAs (P = 0.003) and CONs (P = 0.0001, Table 1). The TKOs had significantly greater tibial intorsion compared to CON (P = 0.045) but were not different from KOAs (Table 1). Inter-rater reliability for both the LSLE and CT measures was acceptable with an ICC range of 0.854 - 0.988 (Table 1).

During level walking, TKOs had a significantly greater 2nd peak knee varus moment when compared to KOAs (P = 0.026) and CONs (P = 0.0001, Table 2, Figure 1). KOAs walked with significantly less foot progression angle vs. CON (P = 0.045), but were not different from TKO (Table 2). The regression model predicting dynamic loading using the mechanical axis (β = 0.898), tibial torsion (β = 0.264) and foot progression angle (β = -0.369) showed a goodness of fit of 0.774 (Table 3).

DISCUSSION:
The TKOs walked with significantly greater dynamic loading compared to KOA and CONs. However, the dynamic loading was significantly predicted by the mechanical axis and the foot progression angle during gait and not by tibial intorsion. For select knee OA subjects, tibial intorsion was a multiplanar deformity which was compensated for with external rotation of the knee. Future studies are needed to associate tibial intorsion to contact forces across the medial tibiofemoral joint. While total knee arthroplasty has been shown to restore mechanical axis alignment, additional longitudinal studies are needed to assess the impact of the procedure on torsional deformity.

Table 1. Mean (SD) long standing lower extremity mechanical axis and computed tomography measures of version for end-stage medial knee osteoarthritis subjects with torsion (TKO) and without (KOA) as compared to aged-matched controls (CON). Inter-rater reliability for the imaging measures is indicated by the intraclass correlation coefficient (ICC).

Table 2. Mean (SD) knee varus moment (KVM) and foot progression angle (FPA) during level walking for end-stage medial knee osteoarthritis subjects with tibial torsion (TKO) and without (KOA) as compared to aged-matched controls (CON).

Table 3. Factors associated with the 2nd peak knee varus moment during level walking: multivariate analysis (n = 24).

FIGURE 1. Ensemble curves of the knee varus moment (A) during stance phase of level walking for end-stage medial knee osteoarthritis subjects with torsion (TKO, n = 6, solid black line) and without (KOA, n = 8, dashed black line) and for age-matched controls (CON, n = 10, gray solid line).