Bowd, Jake, van Rossom, Sam, De Vecchis, Marina, Williams, David, Wilson, Chris, Elson, David, Jonkers, Ilse, Holt, Cathy and Whatling, Gemma (2020) *Knee joint contact forces during gait for patients undergoing high tibial osteotomy.* Osteoarthritis and Cartilage, 28 (S1). S250-S251. ISSN 1063-4584.

Purpose: Varus knee deformity can significantly increase medial knee joint loading that has been demonstrated to accelerate knee degeneration in presence of osteoarthritis (OA). High tibial osteotomy (HTO) surgery is performed in early stages of knee OA with the aim to unload the medial compartment of the tibiofemoral joint and slow down knee degeneration. Therefore, it is clinically important to measure joint loading to better understand whether the clinical aim of the surgery is achieved. External knee adduction moments (EKAM) are routinely used to infer medial tibiofemoral joint load. However, EKAM may not reflect internal joint loading. Musculoskeletal simulations have been shown to be of added value to better understand tibiofemoral joint contact forces compared to EKAM. Patient-specific gait analysis in combination with musculoskeletal modeling allows the analysis of knee joint loading in terms of compartmental contact forces and might be more sensitive to investigate changes in the knee loading pre and post HTO. It is of clinical importance to determine objectively the degree of success of HTO surgery by measuring whether normal knee joint contact forces are restored post operation. The purpose of this exploratory study was to implement a subject-specific simulation pipeline to measure tibiofemoral contact forces in patients undergoing HTO and to report preliminary findings on an individual basis.
Methods: Three-dimensional gait analysis was performed on 6 patients before and approximately 12 months post HTO surgery using a modified Cleveland marker-set. Subjects walked at a self-selected speed on a 10 m walkway instrumented with force platforms for a minimum of 6 trials. Where data issues or outliers were identified, a minimum of 3 trials were used in the analysis. All data was analysed with an identical musculoskeletal modelling workflow. Tibiofemoral contact forces were calculated in OpenSim using a scaled musculoskeletal model. Patient-specific mechanical tibiofemoral angle was implemented in the pipeline. The model integrated an extended knee model allowing for 6 degrees of freedom of the tibiofemoral joint into a generic full-body model. The generic model was scaled to the subjects' anthropometry. Joint angles were calculated using inverse kinematics and then muscle forces and secondary knee kinematics were estimated using the concurrent optimization of muscle activations and kinematics algorithm. The magnitude of the total, medial and lateral tibiofemoral contact forces were determined during the first and second half of stance. For the same trials, external knee adduction moments (EKAM) were calculated in Visual 3D. For this exploratory study, EKAM and joint contact forces are presented for each participant pre and post HTO. Approval for this study was granted by the Wales Research Ethics Committee 3 (10/MRE09/28) and Cardiff and Vale University Health Board. Written informed consent was obtained from each participant prior to data collection.
Results: Mechanical tibiofemoral angle ranged from 5° to 15.4° varus prior to surgery and was corrected to 2.4° varus to 2° valgus post operatively, as

shown in Table 1. Table 2 presents individual changes to EKAM and tibiofemoral contact forces pre and post HTO. Participants 3,5 and 6 who underwent the biggest correction in surgery also reduced their total tibiofemoral peak contact force for the first half of stance, as well as reducing their medial tibiofemoral peak contact force. Interestingly, participant 4 showed increases in both EKAM peaks, total tibiofemoral peak forces and medial tibiofemoral peak forces.
Conclusions: This study used a musculoskeletal model for the first time on a cohort of individuals who underwent HTO surgery. This exploratory study has shown preliminary data indicating that musculoskeletal modelling can be used as an indication of success of HTO surgery. Future research will be undertaken with a greater sample size, sufficiently powered in order to statistically quantify the significance of HTO surgery on tibiofemoral contact forces.

Table 1

Mechanical Tibiofemoral Angle and Gait Speed Pre and 12 Months Post HTO

	Pre HTO mTFA	Post HTO mTFA	Pre HTO Gait Speed (m/s)	Post HTO Gait Speed (m/s)
Participant 1	-5	1.0	0.63	0.79
Participant 2	-5.3	2.4	1.26	1.24
Participant 3	-15.4	-2.0	1.28	1.32
Participant 4	-5.3	0.9	0.85	0.86
Participant 5	-10.1	-0.7	0.51	0.82
Participant 6	-11.5	n/a	0.80	0.94

Negative mTFA; varus alignment. Positive mTFA; valgus. n/a; information not provided due to participant not returning for x-ray post-operatively.

Table 2

Effects of HTO on Tibiofemoral Joint Loading.

	EKAM1 (%BW* Height)	EKAM2 (%BW* Height)	Total TF Peak1 Force (BW)	Total TF Peak2 Force (BW)	Medial TF Peak1 Force (BW)	Medial TF Peak2 Force (BW)	Lateral TF Peak1 Force (BW)	Lateral TF Peak2 Force (BW)
Participant 1	-.83	-1.04	.01	-.97	-.05	-.85	-.10	-.23
Participant 2	-.10	.21	.30	.20	.80	.69	-.47	-.45
Participant 3	-1.33	-1.78	-.60	-.39	-.44	-.58	-.21	.09
Participant 4	.11	.48	.63	1.40	.71	1.39	-.03	.11
Participant 5	-.99	-1.13	-.36	.12	-.39	-.05	-.03	.16
Participant 6	-1.16	-1.03	-1.61	-.23	-.72	.01	-.97	.07

EKAM; external knee adduction moment. TF; tibio-femoral joint. BW; body weight. Std; standard deviation.