Talonavicular compensation for tibiotalar motion in total ankle replacement

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Summary
This study investigates *in vivo* joint kinematics following total ankle replacement compared to healthy controls and the contralateral limb. Dual fluoroscopy assessed tibiotalar, subtalar, calcaneocuboid, and talonavicular joint motion during dynamic activities. Operative limb tibiotalar dorsi/plantarflexion range of motion was decreased compared to the contralateral limb and controls. However, the operative limb exhibited increased talonavicular dorsi/plantarflexion, potentially reflecting compensatory adaptations after surgery.

Introduction
Ankle osteoarthritis (OA) is a painful chronic disease that can cause pain and stiffness in affected joints[1]. After non-invasive treatment options are exhausted, ankle OA is often treated surgically with ankle arthrodesis (AA) or total ankle replacement (TAR). As AA fuses the tibiotalar joint, TAR is gaining popularity as it maintains pre-surgical tibiotalar motion[2]. Studies report that AA and TAR patients often exhibit signs of secondary OA in adjacent joints within 2-5 years of surgery[3], suspected to arise from altered compensatory motion. It is clinically hypothesized that the risk of OA in adjacent joints may be decreased in TAR. However, there is limited information regarding the biomechanics of the adjacent joints including the subtalar, talonavicular, and calcaneocuboid joints. The aim of this study is to identify potential joint motion abnormalities in patients who have received TAR.

Methods
Three healthy participants (2F/1M; age = 36.6±14.1 yrs; BMI = 22.5 kg/m^2) and one patient (F; age = 68 yrs; BMI = 29.8 kg/m^2) who had previously undergone TAR 2.2 years prior (Cadence, Smith and Nephew, UK) were recruited (REB19-1743). Post-operation, the patient regained full mobility, scoring 98 and 93 on the AOFAS and SF-36 health surveys, respectively. The patient exhibited no radiographic signs of OA in joints adjacent to the tibiotalar joint. Participant feet and ankles were imaged at 120 Hz with a DF system (kvp 78, mA 125) while participants performed activities of daily living: walking, step up, step down, and heel rise. A CT scan was acquired of the mid-tibia through toe tips using a metal artifact reduction sequence (Revolution GSI HD, GE Healthcare). The tibia, talus, calcaneus, cuboid, and navicular were segmented on the CT images to generate 3D bone models. A 2D-3D registration process was used to align bone models with 2D DF images and determine bone positions throughout each activity. 3D bone positions were used to determine six degree of freedom tibiotalar, subtalar, calcaneocuboid, and talonavicular joint kinematics and range of motion (ROM) (MATLAB 2024b, USA). Operative limb joint kinematics were quantitatively compared to the contralateral limb and controls using ROM values and qualitatively by looking at the joint angle curve shape.

Results and Discussion
Talonavicular dorsiflexion/plantarflexion (DF/PF) ROM was greater in the operative limb compared to controls and the contralateral limb. However, tibiotalar DF/PF ROM was smaller in the operative limb (Table 1). Qualitatively, the operative tibiotalar DF/PF was similar to the contralateral limb, indicating no improvement in motion due to TAR. However, operative talonavicular DF/PF was notably elevated during late midstance compared to the contralateral limb (Fig. 1). These results suggest that increased talonavicular DF/PF may be compensation for restricted tibiotalar motion.

Table 1: dorsiflexion/plantarflexion ROM for the tibiotalar, subtalar, calcaneocuboid, and talonavicular joints during walking

	Range of Motion (ROM) [°]			
	Tibiotalar	Subtalar	Calcaneocuboid	Talonavicular
Controls	12.5±3.1	6.7±2.2	9.1±2.2	7.4±1.9
Operative	9.1	6.4	7.1	12.2
Contralateral	15.2	7.1	8.4	9.2

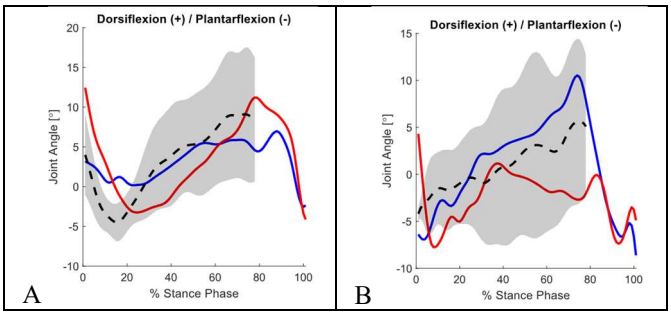

Figure 1: Joint angles for tibiotalar (A) and talonavicular (B) joints during stance for the operative (blue) and contralateral (red) limbs compared to controls (black = mean; shaded = standard deviation).

Conclusions
These findings indicate that the foot adapts to restricted tibiotalar motion by increasing talonavicular motion. Although further studies with larger sample sizes and longitudinal aspects are warranted, these results may be essential for surgical decision making and development of methods to prevent secondary OA throughout joints adjacent to the tibiotalar.

Acknowledgments
We gratefully acknowledge funding from the University of Calgary McCaig Institute and Department of Biomedical Engineering, NSERC, and CIHR.

References
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