The effect of different surgical corrections of fixed flatfoot on its unloaded and loaded behavior

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INTRODUCTION: Adult acquired flatfoot deformity (AAFD) causes the collapse of the foot's longitudinal arch, resulting in talus sliding, forefoot abduction, and hindfoot valgus. In Stage III AAFD, these deformations are permanent and require surgery. Subtalar arthrodesis repositions and fuses the calcaneus under the talus, while triple arthrodesis fuses the subtalar, talonavicular, and calcaneocuboid joints, providing better stability but increasing risks of rigidity and osteoarthritis. Previous finite element (FE) models showed both procedures restore arch height but were limited to one single subject with grade II flatfoot. This study uses a validated dynamic computational model [1], on multiple subjects, to compare arthrodesis techniques for correcting Stage III AAFD under simulated bodyweight conditions

METHODS: Five Stage III AAFD patients were recruited to develop personalized foot and ankle models. Each underwent Weight Bearing Computed Tomography (WBCT) scanning at 0.37 mm resolution pre- and post-subtalar arthrodesis. From these images, pre and post-surgical computational models [1] were produced for each patient. Weight-bearing simulations assessed biomechanics for the pre-op model and for the post-op model under three conditions subtalar fusion, triple fusion (subtalar, talo-navicular and calcaneal-cuboid), and triple fusion with additional manipulation consisting of midfoot plantarflexion and forefoot adduction (triple fusion/double maneuver). Arch height was measured by the medial longitudinal arch angle and navicular centroid height. Hindfoot alignment was measured by ankle complex inversion, while forefoot abduction was assessed using Maery’s angle between the first metatarsal and the talus on the transverse plane. Talo-navicular coverage was determined from distance map calculations and marked for each subject (Figure 2). Additionally, contact forces between the talus and tibia and between the metatarsals and the floor, were measured. Talar surface stresses (dome and medial malleolus) were estimated from the contact forces and areas of contact.

RESULTS: The geometric measurements, expressed as mean ± 95% confidence interval, showed that all surgical interventions corrected the medial longitudinal arch, with slighter better outcomes for the triple fusion/double maneuver. On the frontal and transverse planes, hindfoot alignment and transverse Maery’s angles, reached values close to 0º as in normal feet (Figure 1). At zero load, navicular coverage on the talar head shifted from proximal to distal regions with each surgery and forcing the navicular up during an additional maneuver left the proximal talar head uncovered (Figure 2). At full bodyweight, stress on the talar dome was similar across conditions, but stress on the medial malleolus doubled in the triple fusion/double maneuver condition compared to pre-op (Figure 3). In the pre-op condition, contact forces were evenly distributed among the metatarsal bones, ranging from 15N to 40N. After subtalar fusion, forces remained uniform but increased to 71N at the fifth metatarsal. With triple fusion, the force distribution becomes highly uneven, peaking at 144N under the fifth metatarsal.

DISCUSSION: Overall, the results showed comparable improvements in deformation recovery and foot flexibility across the different surgeries. Subtalar and triple fusion surgeries partially restore medial arch angle and navicular height, while fully recovering from forefoot abduction and hindfoot valgus. Although triple fusion with additional maneuvers improves middle arch restoration, it carries risks of overcorrection, reducing talonavicular coverage, foot mobility, and increasing stress under the fourth and the fifth metatarsal bones. Therefore, subtalar fusion, the least invasive from all three, is recommended for correcting flatfoot.

SIGNIFICANCE/CLINICAL RELEVANCE: Understanding the biomechanical changes at the foot and ankle following different surgical fusion techniques is clinically relevant for selecting and improving surgery for grade III AAFD patients.

REFERENCES:
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IMAGES AND TABLES:

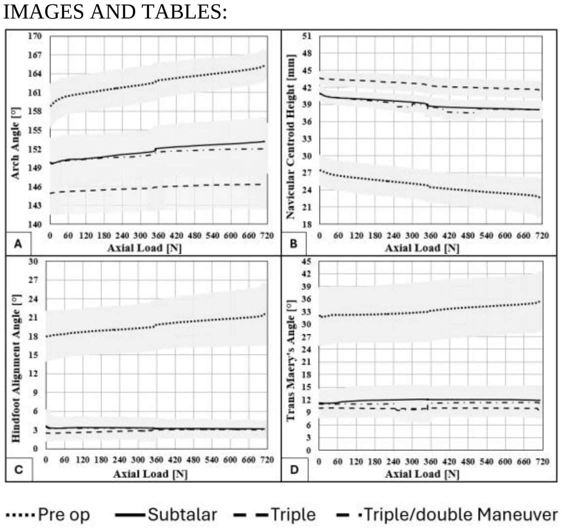

Figure1. Morphological variations in the arch angle (A), Navicular height (B), hindfoot alignment (C) and transverse Maery’s angle (D) during body weight simulations. The results expressed as average among the five

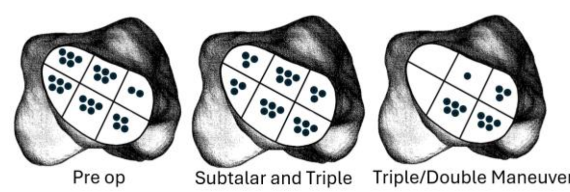

Figure 2. Areas of coverage on the talar head. Each dot corresponds to a patient. Every patient has a coverage in the areas with five dots

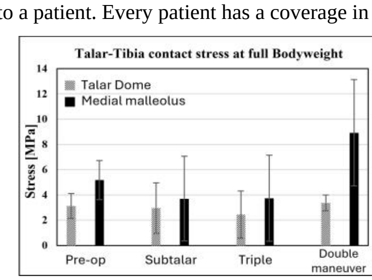

Figure 3. Average and standard deviation of the stress on the talar dome and on the medial malleolus at full bodyweight in the four conditions.