Optimization of the Evans osteotomy Graft size to Minimize the Calcaneocuboid joint pressure: A Finite Element Analysis

Sewon Kim[1], Luca Quagliato[1], Youngbin Lim[2], Kyoung Min Lee[3], Jeicheong Ryu[1] and Taeyong Lee[1]
[1]Dept. of Mechanical and Biomedical Engineering, Ewha Womans University, Seoul, Korea
[2] SIMULIA, Dassault Systèmes Korea, Seoul, Korea
[3]Dept. of Orthopedic Surgery, Seoul National University Bundang Hospital, Seongnam, Korea
Email: tlee@ewha.ac.kr

Summary

This study presents a novel finite element analysis (FEA) methodology to examine the influence of the graft size on the calcaneocuboid (CC) joint pressure after Evans osteotomy. The FEA model includes 28 bones and soft tissues, including tendons and muscles, validated against *in-vivo* plantar pressure and 3D-scanned foot geometry. The proposed FEA model was developed to accurately replicate *ex-vivo* findings, enabling the determination of the optimal graft size for flatfoot correction while minimizing CC joint pressure.

Introduction

Evans osteotomy is a surgical procedure for flatfoot correction, by inserting graft to calcaneus. While generally effective, complications such as CC osteoarthritis, lateral foot pain, and graft detachment have been reported [1]. *Ex-vivo* studies highlight the importance of graft size, but their complexity has shifted toward FEA-based simulations. However, existing FEA models assume pre-rotated foot geometry, neglect post-insertion equilibrium, and exclude muscle/tendon forces and surrounding soft tissues, leading to discrepancies with *ex-vivo* findings [2]. This study aims to develop an advanced FEA model, accurately replicating *ex-vivo* results to determine the optimal graft size for Evans osteotomy.

Methods

This study comprises two stages: foot model validation and Evans osteotomy simulation using Abaqus/Standard. The 28-foot bone geometry was reconstructed from CT data, with 74 ligaments and 6 fasciae modeled as 1D truss elements. Material properties of tissues and boundary conditions (BC), including tendon forces and body weight, were recalibrated. In Evans osteotomy simulation, the graft's high elastic modulus justified treating is as a rigid body, simplifying insertion. Instead of physical insertion, relative rotational motion was applied between osteotomy surfaces as BC, followed by body weight loading.

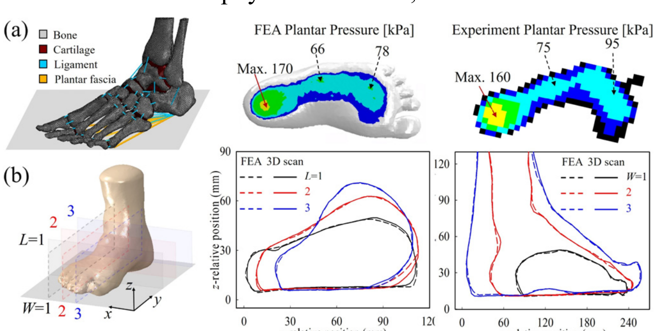

Figure 1: Validation of foot model by comparing (a) plantar pressure and (b) foot profiles from FEA and experiment.

Results and Discussion

The validation model demonstrated strong agreement between FEA and experimental data, with a ~6.3% deviation in plantar pressure and ~5% deviation at foot profiles as in Figure 1, indicating high accuracy of foot model. Osteotomy simulations revealed that maximum CC joint contact pressure was minimized with a 3mm graft. Also, metatarsal rotation exhibited over-linear correlation with graft size, suggesting that a 6 mm graft may lead to overcorrection and increased CC joint pressure.

Conclusions

This study found that 2-4 mm graft reduced CC joint pressure, with a 3mm graft achieving an ~18% reduction. The proposed model aligned with *ex-vivo* studies [3], unlike previous FEA models. These findings support optimizing graft size for personalized surgical planning. The study demonstrates the feasibility of using the FEA for a patient-specific graft selection in Evans osteotomy to enhance the medial arch, while minimizing CC joint pressure.

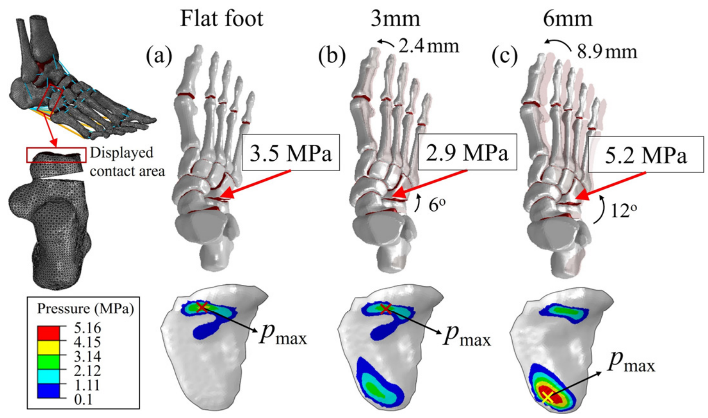

Figure 2: Maximum pressure in CC joint with the graft size.

Acknowledgments

This research was supported by the BK21 FOUR (Fostering Outstanding Universities for Research) funded by the Ministry of Education (MOE, Republic of Korea), National Research Foundation of Korea (NRF-5199990614253).

References

[1] Jara ME. (2017). *Foot Ankle Clin*, 22(3): 573–585.
[2] Xu C et al. (2024). *J Orthop Surg Res*, 19:107, 1–11.
[3] Xia J et al. (2013). *Foot Ankle Int*, 34(2): 261–266.