

Prediction of Pressure Changes at the Subtalar Joint Surface in Different 3D Printing Talar Prosthesis Types

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INTRODUCTION: A 3D printed talar prosthesis is applied to the total talar replacement (TTR) in order to provide better articular surface consistency and mobility at the ankle joint than conventional talar arthroplasty. However, it is not clearly to side effects including the ankle osteoarthritis and necrosis by unnecessary pressure at the adjacent joint of the talar prosthesis and those study is rarely conducted. Thus, to improve those clinical limitations, this study conducted to predict peak pressure at the adjacent joint surfaces of the talus in regard to 3 different infilling rate of 3D printed talar prostheses after TTR as a pilot study to optimize prosthesis model. Several research and development have been conducted but could not clearly report to and stress change at adjacent joint surfaces of the talus. Thus, this study conducted to predict peak pressure change on the adjacent joint in 3 different structure types of 3D printed talus.

METHODS: Based on a validated 3D normal foot finite element model (male; 27 years old; 65 kg) from a previous study [3], post-operated modes were constructed by applying 2 different types of the talar prosthesis (Talar spacer, Ti-Al-V4, $E=113,000\text{MPa}$, $\nu=0.3$, RNX Ltd, Korea). The solid-type model was assigned 100% infilling rate and the shell-type model was modeled by assigning 0% infilling rate with 2mm contour thickness. Ankle joint movement was simulated by assigning 'sliding contact condition' and friction coefficient($\mu=0.5$) considering contact property between the talar prosthesis and bone cartilage. In loading condition, a subject body weight 650N was applied to vertical direction in considering one-leg standing position and superior surfaces of the tibia and fibula were constrained in all directions. The peak pressure was calculated at the subtalar joint (anterior, middle, posterior) and the talonavicular joint. Model construction and pressure prediction were conducted by Abaqus (v2022, Dassault System, France).

RESULTS: Overall, the Solid-type showed a lower peak pressure than the Shell-type in post-operation. Especially, the biggest peak pressure was show at the posterior subtalar joint and the Solid-type (3.04MPa) was showed lower pressure value by 15% than the Shell-type. Also, at the navicular joint adjacent to the talus, the Solid-type (3.04MPa) was tended to have a lower pressure value than the Shell-type (8.64MPa) by 5%.

DISCUSSION: Reflecting those results, the Solid-type (100% infilling rate) may be shown to relieve unnecessary pressure at the at the adjacent joint of the post-operative talar prosthesis than Shell-type (0% infilling rate). Although this study was the pilot test, it could suggest a foundation design of the talar prosthesis modeling based on the Solid-type.

SIGNIFICANCE/CLINICAL RELEVANCE: Infilling rate may show very important variable to relieve unnecessary pressure at the adjacent joint of the post-operated talar prosthesis. Also, it may be essential in further study to consider different infilling rate and inner-structure in the modeling of talar prosthesis.

IMAGES AND TABLES:

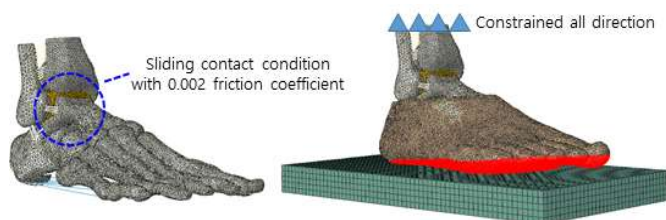


Figure 1. The validated 3D foot and ankle finite element model

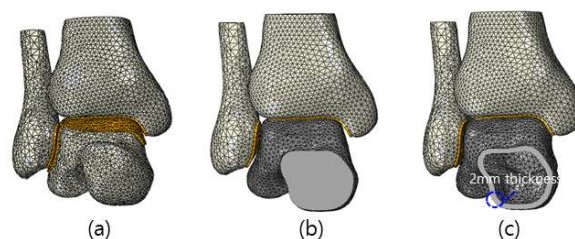


Figure 2. 3 different types of the talus: (a) Normal talus, (b) Solid-type of talar prosthesis, (c) Shell-type of talar prosthesis

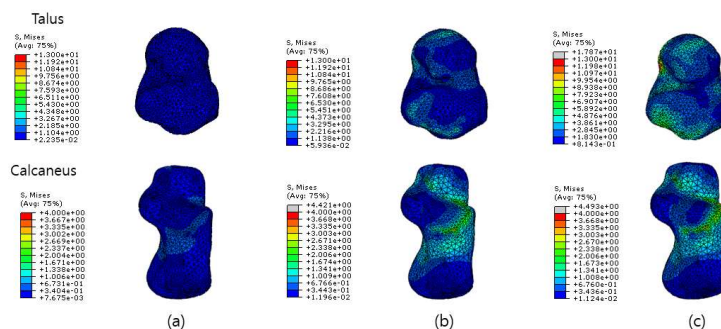


Figure 3. Prediction of pressure change in different types of the talus: (a) Normal talus, (b) Solid-type of talar prosthesis, (c) Shell-type of talar prosthesis