THE FINITE ELEMENT ANALYSIS OF INTERFACE STRESSES BETWEEN THE FOOT AND ANKLE-FOOT ORTHOSES

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INTRODUCTION

Ankle-foot orthosis (AFO) is often used to correct abnormal gait and maintain ankle and foot in neutral position during ambulation. Unsuitable prescription of AFO would cause the increasing of plantar pressure and even ulceration [1]. Currently, the design of AFO still relies on the orthotist's experience and subjective judgments. This often induced a costly "trail and error" approach to obtain an acceptable AFO. There are some studies to discuss the mechanical behavior in different types of the AFO. But interface stresses between foot and orthoses is seldom discussed especially the shear stresses [2]. The objective of this study was to investigate the interface stress between foot and AFO by establishing a 3D finite element model.

METHODS

A female subject (aged 26) was selected as the modeling target. To setup the material property of the soft tissue, the load-displacement curves of the soft tissues in four regions of the foot were recorded and the Young's modului were calculated from these curves. The contact pressure between the foot and AFO under foot flat condition were measured by the Novel Pedar (NOVEL GmbH Pedar) to valid the finite element results.

The finite element geometry of the foot-AFO structure was established based the CT images. To simplify the computational aspect, the bone structure was modeled as a single entity that is no joint is modeled. The surface-to-surface contact elements were placed between the foot and orthosis with a friction of coefficient 0.5. The proximal anterior surface of the leg was constrained in the anterior and posterior directions to model the strap constraint. The entire bottom area of AFO was fixed to simulate the foot flat condition. Besides, the heel and toe regions of the AFO bottom area were fixed respectively to simulate the heel strike and toe off stages. The loading was applied as a displacement on the superior surface of the leg bone. This displacement increased until the reaction fore reached the body weight for foot flat condition and 125% body weight for heel strike and toe off conditions.

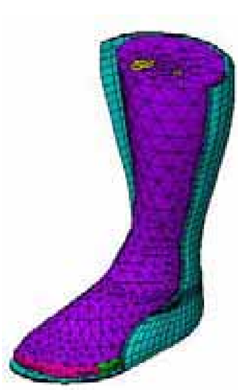

Figure 1: The finite element mesh of the foot-AFO structure.

RESULTS AND DISCUSSION

The finite element mesh of the foot-AFO structure was shown in Figure 1. The differences of averaged contact pressures between the EMED measured results and finite element simulated outcomes were less than 10% which validated the finite element model.

For the foot flat condition the peak contact pressure occurred on the forefoot region which consistent with general biomechanical observation on foot (Figure 2). For the heel strike and toe off conditions, the peak interface stresses happened on the heel and toe regions respectively and this is due to the constrain conditions. Comparing with the foot flat mode, the interface stresses could be increased by more than 200% at toe off or heel strike modes, even though, the loading was increased by only 25%. Moreover, this large increasing of interface stress occurred on both the contact pressure and the shear stress.

CONCLUSIONS

The results of this study indicated that not only the contact pressure but also the interface shear stress plays an important role in the biomechanical evaluation of AFO. Both the loading amount and boundary condition (postural) are vital in determining the interface stresses distributions. The loading and boundary conditions affect the interface stress distribution tremendously; therefore a more realistic loading is necessary for the evaluation of AFO and the modeling of joints might be required for loading conditions other than foot flat.

REFERENCES

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2. Nowak MD, et al., *Journal of Rehabilitation Research and development.*, **37** pp.273-281, 2000

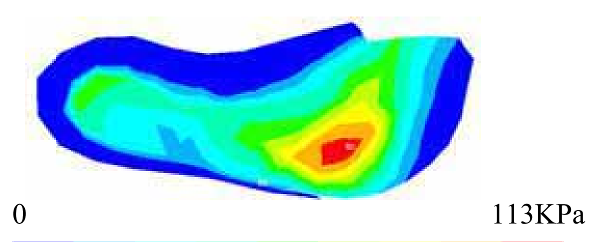

Figure 2: The peak contact pressure occurred on the forefoot region during the foot flat.