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Fabrication of Ankle-Foot Orthoses using Selective Laser Sintering Technology

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FABRICATION OF ANKLE-FOOT ORTHOSES USING SELECTIVE LASER SINTERING TECHNOLOGY

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INTRODUCTION

Passive dynamic ankle-foot orthoses (AFOs) are often prescribed to improve gait performance for those with various neuromuscular disorders. Designs and materials used for AFOs range from simple polypropylene braces to advanced custom carbon fiber dynamic AFOs that passively store and release mechanical energy during gait. AFO designs vary in the shape and length of the foot component as well as the stiffness and length of the tibial component, depending on the desired functional outcomes. However, the current fabrication technology is not ideally suited for refined customization of AFO characteristics to optimize performance, or for rapid low-cost, high volume manufacturing and global distribution.

A promising engineering solution for producing customized dynamic AFOs is the application of Selective Laser Sintering (SLS), which is a versatile manufacturing technology that provides advantages over traditional methods and has already been successfully used to fabricate prosthetic sockets for lower limb amputees (e.g., Faustini et al., 2006). Thus, the primary objective of this study was to explore the feasibility of using an SLS-based design, analysis and manufacturing framework to produce subject-specific passive dynamic AFOs in a cost effective manner.

METHODS

To facilitate a direct comparison of the SLS fabricated AFO with a commercially available AFO, a replica of the carbon fiber Dynamic Brace (CF-AFO; Advanced Prosthetics and Orthotics Inc.) was generated. The framework included the following steps (Fig. 1): 1) determining the bending stiffness of the CF-AFO, 2) developing a surface model of the AFO from scanned image data, 3) developing a Computer-Aided Design (CAD) model of the AFO from the surface model, 4) performing a FEM analysis of the CAD model using anticipated load conditions, 5) iteratively modifying the strut dimensions in the AFO CAD model to reproduce the stiffness and structural characteristics of the CF-AFO, and 6) using SLS to fabricate a working prototype using Rilsan^{TM} D80 material.

RESULTS

The proposed framework proved to be a feasible process to generate AFOs directly from the scanned image data. The design characteristics were nearly identical to the carbon fiber Dynamic Brace (e.g., interior geometry in contact with the patient, bending stiffness). The primary geometric difference was that the strut dimensions in the SLS-AFO needed to be increased to match the CF-AFO bending stiffness (Table 1). However, the weight was 49% less than the CF-AFO and the cost for materials to produce the SLS-AFO was much less ($500 USD per AFO using Rilsan^{TM} D80 compared to ~$7,000 USD retail for the Dynamic Brace AFO).

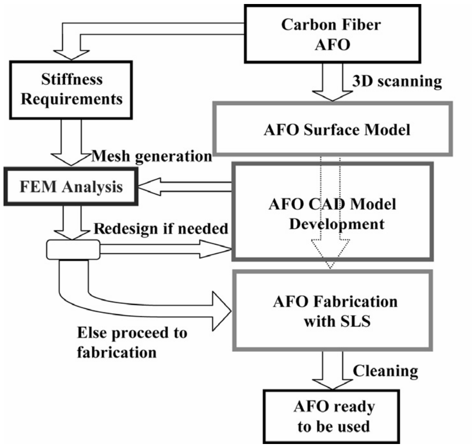

Figure 1. Framework for the AFO design and SLS fabrication to duplicate the CF-AFO design characteristics.

Table 1: AFO Characteristics.

Property\AFO Material	Rilsan^{TM} D80	CARBON FIBER
Weight (g)	575	1130
Cross sectional area of each strut (mm^2)	581	220
Rotational Stiffness (N-m/degrees)	10.2	10.7
Cost (USD)	500	~7,000

DISCUSSION

The present study used an existing AFO design to assess the feasibility of the SLS-based framework. One of the primary advantages of the present framework is that it allows for systematic and controlled design modifications in the AFO shape, which permits the exploration of the relative advantages of various AFO designs and the ability to fabricate subject-specific AFOs. To produce a subject-specific AFO, existing designs can be simply scaled to a scanned image of the patient's limb and the framework applied to optimize the AFO design characteristics to suit the patient's specific needs. This is the focus of our present work.

REFERENCES

Faustini, M.C. et al. IEEE Trans Neural Syst Rehabil Eng. 14, 304-10. 2006.