**New Techniques Advance Foot Orthosis Design**

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**Introduction**

Current orthotic theory is limited by fabrication design techniques based upon vacuum pressing a single thickness sheet of material. This produces a uniformed contoured shell with limited dynamic response. This research presents a new concept of using computer design and milling to make orthotics more rigid by increasing the thickness across the arch. Such a device could be tailored to an individual’s biomechanics and symptoms.

**Methods**

Using currently available software and CNC milling machines, (Delcam, Birmingham, UK) orthotics

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**Figure 1.** Using Delcam OrthoModeler software a 3-D orthosis was designed from foot data. The data was then sent to a CNC machine for milling. A. Standard neutral shell foot orthosis B. Same orthosis design with added ridges to stiffen the arch area.

**Figure 2.** Orthosis was fixed to a floating X-Y platform and arch was compressed while stress strain data recorded using a Test Resources materials testing machine.
were made for ten subjects (8 female, 2 male mean age 36.7 years) with no history of foot pain, who did not previously wear orthotics but did demonstrate visible calcaneal eversion during the gait cycle. A neutral shell foot orthosis was fabricated along with an orthosis that was designed and milled with a thicker area across the arch to create a more rigid device. The orthosis was fixated and tested on a materials-testing machine and reactive forces to loading were compared to the neutral shell standard orthosis of a single uniform thickness. Dynamic in-shoe pressure analysis was performed with both types of orthosis over an average of 10 steps. (Tekscan, South Boston MA) Pressure, force, and impulse (area under curve) were analyzed.

Results

Resistance-to-arch compression was increased in the varied-thickness orthosis compared to the uniform thickness shells (14.6 ± 0.2 N/mm vs 8.2 ± 0.23 N/mm $P = 0.03$). In all subjects the medial-to-lateral heel pressure was increased in the varied-thickness orthosis as was the impulse.

$(80 \pm 26 \text{ KPa vs } 46 \pm 32 \text{ KPa}, P < 0.001)$

$(89.52 \pm 14.8 \text{ N}\cdot\text{s vs } 51.93 \pm 12.6 \text{ N}\cdot\text{s}, P < 0.001)$

Figure 3. Average pressure map of A. Standard Shell B. Added X-Arch area in the same shell design. Note medial pressure distributions.

Graph 1. Stress-Strain graph of the linear portion of the curve showing the X-Arch is stiffer than the standard orthosis. The greater the stiffness, the greater the slope.

Graph 2. Mean pressure at the heel was greater for the X-Arch orthosis than the standard orthosis.

Graph 3. Mean impulse at the medial heel was greater for the X-Arch versus the standard orthosis, suggesting it was pushing back against the heel with more force.
Conclusions

This study demonstrates that by varying the thickness of the orthosis shell, greater stiffness as well as dynamic responses can be changed. This could possibly lead to new way of approaching orthotic design that produces a more dynamic response to loads during gait. Such an orthosis could be designed to restrict motion or allow motion at various times of the gait cycle depending on what is needed based on an individual’s biomechanics and pathology.

Learning Objectives

1. Understand the basic mechanics of a foot orthosis.
2. Understand how thickness plays a role in dynamic response.
3. Identify how such designs could be altered to address various pathologies.

Acknowledgment: The authors would like to thank Mile High Orthotics Labs and Delcam for their assistance in this research.

New Techniques Advances Foot Orthosis Design

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Introduction

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Methods

Using currently available software and CNC milling machines, (Delcam, Birmingham, UK) orthotics were made for ten subjects (BF, 2M mean age 36.7 years) with no history of foot pain and did not suffer from the conditions described in the study. Two units from each subject were made from the same composite material, one of these was a reusable09 smoother shell to allow for variances in the thickness during the gait cycle. A neutral shell foot orthosis was fabricated along with an orthosis that was designed and milled with an area across the arch thicker to create a more rigid device. The orthosis was fitted and tested on a materials testing machine and reactive forces in loading were compared to the neutral shell standard orthotic of a single uniform thickness. Dynamic testing was performed on the fabricated devices in two types of orthotics, one of an average of 10 steps. (Texas, South Boston MA) Pressure, force, and impulses (area under curve) were analyzed.

Results

Resistance to arch compression was increased in the varied thickness orthotics compared to the uniform thickness shells. (14.6 ± 5.2 N/mm vs. 8.2 ± 2.23 N/mm, p=0.02). In all subjects the medial to lateral heel pressure was increased in the varied thickness orthosis as was the impulse. (90 ± 1.2 ±52 XPA vs 48 ±32 XPA, p=0.01) (90.02 ±16.55 N/mm vs 91.99 ±9.65 N/mm, p=0.081)

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