EFFECTS OF MATERIALS, DESIGNS AND HEAT TREATMENT ON SAFO MECHANICAL PROPERTIES: A PRELIMINARY REPORT

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INTRODUCTION

Solid ankle foot orthoses (SAFO) are one of the most common designs utilized for stabilization of the foot and ankle in patients with a lower limb neuromuscular deficit. Since its advent, SAFO have been made with a wide range of designs (trim lines, reinforcement techniques) and materials (thermoplastic and thermoset resins). In practice orthotists generally utilized polypropylene due to its low cost, ease of fabrication and resistance to fatigue. There are two major polypropylenes: homopolymer (homoPP) and copolymer (copolymer). The former is pure resin while the latter has a small amount of polyethylene in the resin to improve cold climate flexibility. More recently discontinuous carbon fibre has been added to homoPP to improve stiffness. Beside material variety SAFOs can incorporate corrugations or prepreg composite inserts for increased stiffness. Furthermore, the material properties in the finished homoPP orthoses could be altered by heat treatment (e.g. annealing). Practitioners will benefit from a study in which physical characteristics of SAFOs with various materials, reinforcement techniques and annealing are quantitatively investigated.

METHOD

Eight SAFOs were fabricated following industrial guidelines with three types of thermoplastic sheetstock and two reinforcement methods. The SAFO design followed Simon's total contact concept with mid malleolus trim lines. One reinforcement method incorporated the Clark and Lundsford's corrugation technique. The second reinforcement method utilized Bedard's homoPP/carbon/glass prepreg inserts (CompCore® Becker Orthopedic). The three sheet materials were natural homoPP, copolymer and a new material, which is homoPP infused with discontinuous carbon fiber. The sheets were all in a 3/16" gauge.

The annealing treatment was conducted in a Gruenburg convection oven with a Watlow PID controller. An Atkins digital thermometer was clipped to the SAFO in the oven with a flexible bare tip probe. The SAFO was placed in the oven at room temperature and subjected to a ramp up heating of 50°F/hour with a 185°F ceiling. A two-hour plateau was followed by an equal ramp down to room temperature.

The test procedure for stiffness and ROM utilized an apparatus developed in a previous study. A motorized device with an inline torque sensor (Transducer Tech Inc.) and optical encoder was used to move the SAFO at a speed of 5°/s with peak resistance torques of 20 Nm in both dorsiflexion and plantarflexion. The data were sampled at a rate of 1,000Hz. Each test lasted 120 s and repeated three times for each sample.

RESULTS

For example (Figure 1) for straight design, the ankle ROMs are 9.71 ± 0.22^o, 10.25 ± 0.14^o and 10.11 ± 0.30^o for carbon composite, copolymer and homopolymer respectively. In addition, the ROMs are reduced when the designs are changed from straight to either corrugated or CompCore. For instance, the ROMs for carbon composite are 9.71 ± 0.22^o, 8.95 ± 0.19^o and 8.62 ± 0.13^o for straight, corrugated and CompCore respectively.

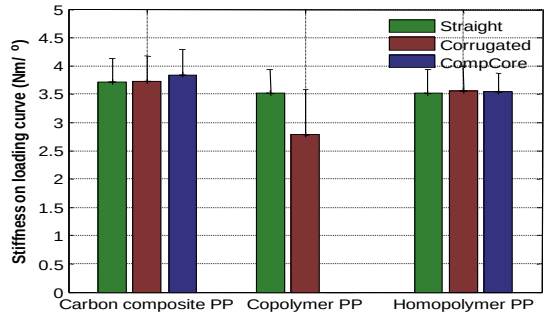

Figure 1: Torque stiffness at prescribed resistance (10 Nm)

Annealing does show an effect on reducing the ankle range of motion. As illustrated, the ankle ROM is reduced from 10.82 ± 0.80^o to 10.03 ± 0.27^o. However, the change does not reach significance level. Overall, the ankle ROM after annealing is comparable to that for corrugated design. SAFO with CompCore shows significantly smaller ROM (i.e. 8.58 ± 0.11^o) compared to other designs.

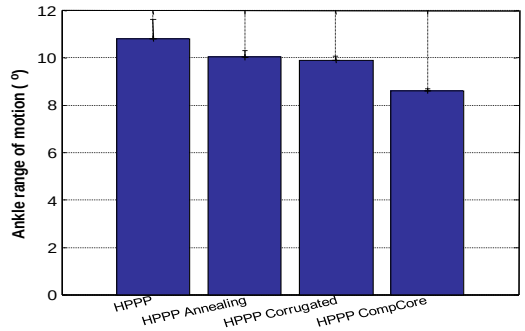

Figure 2: Effects of annealing - ankle range of motion

DISCUSSION AND CONCLUSION

In summary, we have systematically evaluated the effects of materials, designs and heat treatment on the material properties of SAFOs and the outcome of this study has indicated all factors can impact the mechanical properties of the fabricated SAFOs to different levels. For example, reinforcement does improve the SAFO stiffness in most of the cases. In addition, adding carbon fibres into the homopolymer significantly improves its mechanical properties. Annealing also improves stiffness.

CLINICAL APPLICATIONS

The various physical characteristics demonstrated in a range of materials and reinforcement techniques will be useful for practitioners to improve the criteria of both design and prescription.

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