A Parametric study of an Ankle-Foot Orthosis

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INTRODUCTION
Drop foot can be defined as an impairment or lack of function of ankle and toe dorsiflexors [1]. This can due to muscular or nervous damage. One treatment to improve dorsiflexor function is to wear an ankle foot orthosis, a brace that stabilises the foot and lifts it in an upright position while the foot swings.

The aim of this study was to find a good material for a brace. It should not be to stiff, or ankle could not bend during stance, in normal gait og walking down stairs Nor should it be to ductile or it would not be able to lift the foot during toe of. The rods of the brace experience extensive stretching, torsion and bending while the brace is being used, so care must be taken to avoid fatigue of the materials used in the brace.

Finite element modeling (FEM) is widely used in biomechanics. Through FE-analysis parametric study can be made of the brace without actually creating new physical braces.

METHODS
A person-specific drop foot brace was made by vacuum infusion. Test specimens of the same materials were also made. Tensile testing was done on the specimens, in order to find the relevant material parameters used for this specific brace. The specimens were tested in transverse and longitudinal directions of the fibers. A finite element model of the brace was created in commercial FE-code Abaqus. An orphan mesh of the brace was created from an optic 3D scan of the inner surface of the brace. The CAD software program, CATIA, was used to convert the orphan mesh into a geometric part, which was later meshed in Abaqus. Material parameters from the tensile testing were applied to the model. Parameters for other materials were also applied to the model. Two FEM models were created, one for the whole brace and one for the lateral rod of the brace. In both cases the sole was fixed while the upper part of the brace displaced forward in order to simulate the stance phase in normal walking.

RESULTS AND DISCUSSION
From the orphan mesh of the whole model see figure 1, the lateral rod was extruded. The rod model shown in figure 2 consists of a perlon fiber reinforced acryl. The contours at the figure show the maximum through thickness compressive strain in the lateral rod. The highest compression strain is found in the lower frontal region of the rod, and is for this specific case 2.1%. The maximum tensile strain (not shown here) found in the lower posterior region of the model is slightly smaller, 1.7 %, than the compression strain.

Based on the finite element model a number of material candidates are investigated. For example can parts of the lateral rod reinforced using carbon or glass fiber in order to obtain additional stiffness and strength of the brace.

Here attentions are made both regarding the tensile and static and fatigue strength or the material.

![Figure 1: Finite element model of a drop foot brace.](image1)

![Figure 2: The deformed lateral rod from the drop foot brace with perlon fiber reinforcement. The contours show the through thickness largest compressive strains.](image2)

CONCLUSIONS
The finite element method is found to be a strong tool improving the material used in a biomechanical device. Based on simulations, a large number of expensive trial and error iterations can be avoided.

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REFERENCES