DEVELOPMENT OF A PIPELINE FOR 3D PRINTED CUSTOMIZED PLANTAR FOOT ORTHOSIS BASED ON FEM AND GAIT ANALYSIS

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Introduction

Plantar insoles (PI) are among the most commonly used external supports to treat musculoskeletal disorders. It has been reported that they provide therapeutic benefits via direct mechanical and neuromuscular effects on the lower extremities [1]. Even though recently computer aided technologies have been included in the design and production of PI, which were generally based on plaster casting and vacuum forming techniques, the subjective knowledge required by practitioners and lab technicians to develop PI has not been removed yet [2]. Among the current limitations we should consider the postural and pressure adjustments made through various deformation functions by the technicians and the impossibility for the patient to try the PI prior to purchasing it [2]. The aim of this study was the development of a methodology for planning and testing insoles through finite element modelling (FEM) combined with gait analysis and 3D printing.

Methods

A flatfoot geometry was acquired with a 3D scanner (Structure 3D). Plantar pressure data were acquired by pressure insoles (PedarX, Novel) during walking at self-selected speed at the manufacturer site. The foot-floor angle during stance was also measured through a markerless technique [3]. An stl surface was generated from pressure data and processed through Blender, Simplify 3D and PrusaSlicer: three insoles with different infills or inserts were designed and one was 3D printed (Bioflex, straight filling, 90% infill, 3D-DELTA WASP-4070). The behavior of the designed insoles was tested in FEM (Abaqus): a previously developed foot model was scaled to match the subject-specific foot geometry, and both foot-floor angles and loads, acquired during gait, were used as boundary conditions [4]. Simulations with and without the three insoles were carried on and the results validated through the comparison with the experimental pressure recorded during gait. Simulated pressures and internal stresses in the plantar soft tissues were compared across the 3 insoles.

Results

Results are reported in Figure 1 and Table 1 in terms of pressure distribution and Von Mises stresses.

Results show that a similar value of peak Von Mises stresses was obtained with the Cad cam and straight infill PIs, in correspondence of the same plantar aspect of the foot (5th metatarsal head), even though a higher peak pressure was obtained.

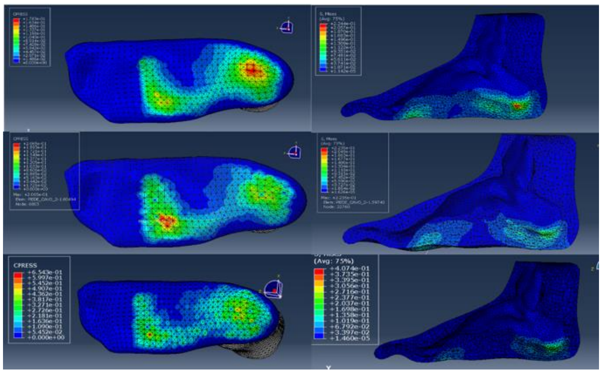

Figure 1: Pressure and Von Mises stresses distribution on the foot with the 3 PIs.

PI	Peak Pressure	Peak Von Mises
Cad Cam solid infill	144 kPa	227 kPa
Straight infill with 2 inserts honeycomb	209 kPa	230 kPa
Infill 15% Full honeycomb	734 kPa	450 kPa

Table 1: Pressure and Von Mises stresses on the foot with the 3 PIs: peak values.

Conclusions

The simulated pressure and the internal stresses allowed to quantitatively assess the effects of the designed insoles, hence the proposed approach can be used to predict the effects of the designed PI prior to its production. This can aid in planning the insole without the need to perform the traditional long trial-and-error procedures as well as removing the subjectivity associated with the technician. Results showed still a better performance of the PI realized with CAD-CAM approach; therefore future developments will include trying different filling materials, slicing, inserts, and filling distribution.

References

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