The TexiSense « Smart Sock » - Textile Pressure Sensor and 3D Real-time Finite Element Model of the Diabetic Foot for a Daily Prevention of Pressure Ulcers

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Introduction

The term « diabetic foot » refers to a set of foot pathologies essentially stemming from the neuropathy and arteriopathy of the lower limb associated with diabetes mellitus. Chronic ischemia weakens the healing potential and favours the development of wounds on a more vulnerable foot. Friction or repeated micro-traumas can lead to an ulceration (which in turn can end up in an amputation) that will remain unnoticed because of the somato-sensory deficiency. The current prevention techniques largely relying on visual inspection of the foot and enhancement of the foot/insole interface are not fully satisfying as the prevalence of plantar ulcers remains very high [1].

Methods

A device for the prevention of plantar ulcers – called "Smart Sock" is described. It consists of (cf. Fig. 1):
1. A sock made of a 100% textile pressure sensing fabric developed by the TexiSense company;
2. A microcontroller running a biomechanical model of the soft tissues of the foot of the diabetic person;
3. A vibrating watch (or a smartphone) used to warn the bearer if an overpressure pattern threatens the soft tissues integrity.

Fig. 1: *Overview of the "smart sock" device.*

Internal overpressures within the soft tissues, especially nearby bony prominences are likely to evolve into deep foot ulcerations. A linear Finite Element biomechanical model of the foot is used to compute estimates of internal pressures magnitudes based on the external pressures measured by the sock/sensor. The device sends a vibro-tactile alert in case of occasional overpressure or excessive stress dose accumulated during daytime activities.
Thanks to the linear nature of the model its global deformation can be computed as a linear combination of a set of elementary deformations pre-computed off-line and stored in the device memory [2].

Results

Internal stresses and stress doses are estimated in real-time as the pressure values reading and the Finite Element model update require less than 100 milliseconds. Figures 2 and 3 show a colormap of the Von Mises equivalent internal stress on a sagittal slice within the 3D model of the foot.

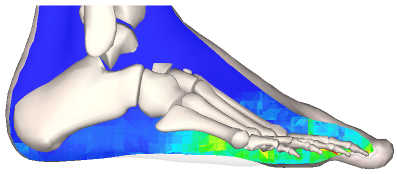

Fig. 2: *Internal pressure patterns in forefoot stance.*

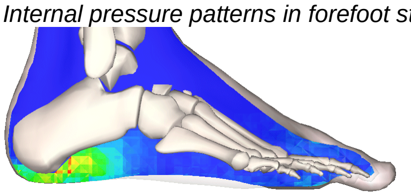

Fig. 3: *Internal pressure patterns at heel contact.*

Discussion

The TexiSense "Smart Sock" can be designed so that, when worn, pressure sensors fall onto sensitive anatomical areas such as the dorsal side of the toes or the posterior side of the heel, which makes it also possible to monitor regions located outside the sole of the foot.

Clinical relevance

The continuous use of the device, compatible with daytime activities of the diabetic person, helps compensate for the lack of attention in the prevention of pressure ulcer formation.

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Conflict of Interest None.

References

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