Real time embedded foot pressure monitoring and subject specific biomechanical modelling: an innovative coupling for diagnosis and treatment in orthopaedics.

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Objective: Plantar pressure monitoring systems can be clinically used either to detect overpressure areas (e.g diabetes mellitus) or to analyse pressure patterns during standing and gait. However, the significant cost of current technologies and their measurements limited to the plantar part of the foot do not allow any real time nor embedded assessment of the pressures exerted all around the foot and the ankle. In addition, to our knowledge, nothing has been developed outside the research laboratories to estimate in real time the stresses that might appear inside the tissues and/or at the interface with the bones. Only a few finite element models of the foot have been developed, among which none is subject-specific. Our team has come up with an innovative approach based on a textile sensor able to continuously monitor pressure all around the foot and the ankle, associated with a parametric finite element model of the foot able to integrate those measurements and predict internal stress distributions during gait or stance issues like neuropathic ulcers.

Design: A fully wireless, customizable and washable ‘smart sock’ has been designed, which is made of a textile able to measure pressure under and all around the foot in real-life conditions. This device is coupled with a subject-specific finite element model that simulates the internal stresses within the soft tissues of the foot induced by the external, surface pressures measured by the Texisense “smart sock”. A number of derived stress indicators can be computed based on that analysis, such as the accumulated stress dose or peak pressures near bony prominences during gait.

Results: Preliminary studies showed that the smart sock is a functional device that is comfortable, easy to use daily and also valid for foot pressure measurement. Furthermore, the finite element model of the foot is able to simulate the impact of surgery, orthotics, biomechanical adjustments or podiatry treatments on internal stress distributions as well as articular movements within the foot. This computation can be carried out in real-time which makes it suitable for gait analysis where high frequency measurements are needed to accurately capture the stress patterns.

Conclusion: Coupled with finite element model, the portable TeXiSense device allows real time, long-term, cost effective pressure measurement of foot external and internal stress. There are many applications ranging from the prevention of ulcers of diabetic foot in the monitoring of the biomechanical consequences of the foot’s surgery or orthotic devices optimization. Thanks to the subject-specific biomechanical modelling, a personalized foot ulceration risk scale can be devised for each individual by accurately considering the individual’s own foot morphology and condition.

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