THREE-DIMENTIONAL MODEL OF THE FOOT AND PRESSURE SOURCE TO SIMULATE RADIAL WAVE THERAPY

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Introduction

Radial wave therapy has been increasingly used for the treatment of a variety of conditions including the management of pain related with the inflammation of the connective tissue in the foot (plantar fasciitis and Achilles tendonitis). While this therapy is relatively widespread, there is no conclusive clinical proof that it is effective. Also, at this point in time the understanding of the exact mechanism through which the method may work is at the level of speculation. In the open literature, radial wave therapy is often confused with the focused shock wave therapy. However, the two methods are very different in terms of the way that the pressure wave is generated and distributed to the body. In the focused shock wave therapy, a high-amplitude pressure wave is generated outside of the body and the entire wave energy is focused on a single point inside the body. In the radial wave therapy, a ballistic pressure source is used; a metal object of 6-15mm in diameter (an applicator) is applied superficially to the location that has to be treated. Pressure pulses are generated when a pressure driven projectile hits the applicator. These pressure waves propagate in all directions. While the pressure wave generated in the shock wave therapy has been well investigated, there is little information on the waves generated by radial pressure therapy. We created finite element models of the foot and of the ballistic pressure source to simulate the mechanical effects of the treatment.

Methods

A simplified model of the pressure wave device consisting of only the applicator and projectile was constructed using the ANSYS finite element package. The applicator was modelled as a rigid object suspended on a spring-damper system representing the constraint from the casing. The parameters of the spring-damper system were determined experimentally.

A three-dimensional geometry of the foot was reconstructed using the Simpleware Software and based on MRI images of the foot of a 32 year old female. The foot model comprised of bones, soft tissue, plantar fascia, and Achilles tendon, which were all represented as three-dimensional objects. The calcaneus, talus, tibia, and fibula were represented as separate objects, whereas the rest of the bones were lumped together. The adjacent bones were connected with cartilage. All the bones had a cancellous core and a cortical outer shell. The material properties for the bone, soft tissue, plantar fascia and cartilage were taken from [Wu, 2007]. Meshing was performed using the ANSYS Workbench. The FE model was then exported into the LS-DYNA software which was used for the simulations of a single pressure pulse which was generated when the projectile moving at 15-20m/s collided with the applicator.

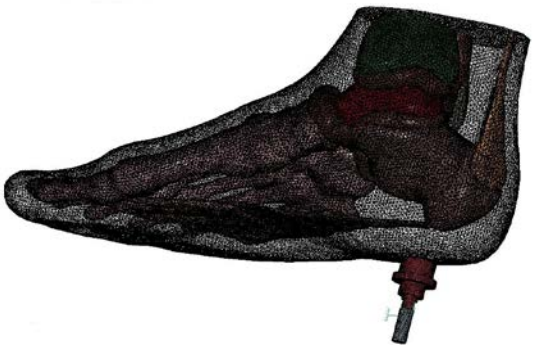

Figure 1: The finite element model.

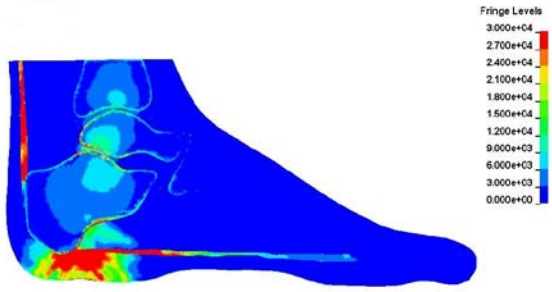

Figure 2: Stress distribution in the plane of the second ray of the foot at 1ms after the impact.

Results and Discussion

The simulation shows that in the soft tissue the pressure wave is mainly confined to the heel pad. Once the wave reaches the stiff structures in the foot it rapidly propagates through the bones and connective tissue, whereas in the soft tissue it is quickly dissipated. The highest stress values are observed in the plantar fascia and cortical bone at the planter fascia insertion point. However, high stresses are also observed in the cortical region of the calcaneus which could indicate that this region may be affected by the treatment.

References

L. Wu, Clinical Biomechanics, 22:221-229, 2007.