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FLUID SHEAR STRESS ON OSTEOCYTE UNDER ULTRASOUND STIMULATION: FINITE-ELEMENT MODEL

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1. Introduction

Ultrasound (US) stimulation of bone remodeling remains an open question as the underlying mechanisms involved are still poorly understood. Among the possible hypotheses, the propagation of ultrasonic waves in bone tissue could generate acoustic streaming (AS) resulting in fluid shear stress exerted on the wall of osteocytes known as the mechanosensitive conductors of bone remodeling. Osteocytes are dendritic cells, ubiquitous in the bone ECM forming a complex micrometric 3D network called the lacuno-canalicular network (LCN). A first finite-element (FE) model is proposed to investigate the effect of US stimulation on a network of 3 osteocytes aligned in the thickness of an osteon, surrounded by a fluid layer and embedded in a rigid extra-cellular matrix (ECM). The influence of a wavy ECM/fluid interface [1] on the wall shear stress (WSS) level is considered.

2. Materials and Methods

In order to implement relevant boundary conditions, we focus on an osteon unit delimited by the cement line (C line) as the outer boundary and the Haversian canal (H canal) as the inner one. Between these two boundaries, we consider a network of 3 osteocytes whose cell body is housed in an ellipsoidal lacuna and connected by one process inside a canaliculus full of fluid considered as salt water at 37°C. A 2D axisymmetric FE model is implemented on Comsol Multiphysics (v. 6.0) to estimate the WSS at the osteocyte surface induced by the AS in the fluid [2]. The boundary conditions are summarized in Table 1. A first order oscillating velocity \mathbf{U}_1 is imposed normal to the ECM/fluid interface to model a harmonic acoustic wave at 1MHz with an amplitude of displacement d_0 equal to 0.4nm. Two geometries of canaliculus are compared:

straight and wavy.

	Laminar flow	Acoustics
Cement line	Wall (no slip)	Wall (no slip)
H canal	Open boundary	Z continuity
ECM/Fluid	Wall (no slip)	$\mathbf{U}_1(\omega) = i\omega d_0 \mathbf{e}_r$
Fluid/cell	Wall (no slip)	Z continuity

Table 1: Boundary conditions. Z: normal acoustic impedance.

3. Results

The geometry of the canaliculus has a strong influence on the WSS.

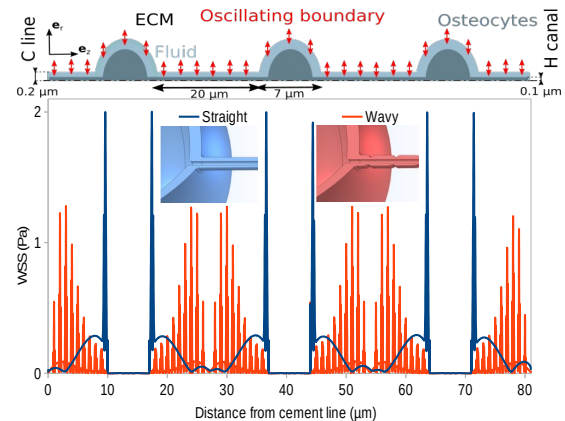


Figure 1: WSS along the wall of the 3 osteocytes.

4. Discussion and Conclusions

This preliminary study shows that harmonic ultrasound stimulation can induce WSS level greater than 0.8 Pa, known as the physiological threshold to trigger bone remodeling [3]. The value of d_0 needs to be further investigated. Moreover, the model can be improved by integrating the osteocyte elasticity and by adding processes.

5. References

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