Finite Element Modeling of an Uncoiled Cochlea Using Synchrotron Radiation-Phase Contrast Imaging

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1. INTRODUCTION

The cochlea is the spiral shaped end organ of hearing that contains the basilar membrane (BM) which houses the Organ of Corti with thousands of sensory hair cells. These hair cells are responsible for transducing the mechanical vibration caused by sound energy to electrical impulses which are then transmitted to the brain. Although the entire BM vibrates during stimulation, it has been shown that the perceived sound pitch is linked to the location of maximum deformation along the BM [1]. Computational models of cochlear biomechanics could potentially be useful in applications such as tuning of cochlear implants; however, current models adjust the BM Young’s modulus to match the Greenwood function but often assume simplified cochlear anatomy. The objective of this study is to investigate the effects of a realistic cochlear shape on the tuned BM Young’s modulus.

II.METHODOLOGY

A finite-element model of an uncoiled cochlea was constructed. The cochlear model is a fluid-filled duct, which has a circular cross-section. The cochlear dimensions were derived from Synchrotron Radiation-Phase Contrast Imaging (SR-PCI) scans (Fig. 1). The cross-section of the cochlear ducts varied along its length. The variations were based on measurements at 5° intervals from the cochlear base to the apex. Material properties, and boundary conditions were taken from the literature [2], and the BM Young’s modulus was calibrated so simulation results matched the Greenwood function over the auditory frequency spectrum (20 to 20000 Hz).

A diagram of a metal object

Description automatically generated with medium confidence

Fig 1. Representation of the uncoiled cochlea using SR-PCI scans.

III.results & discussion

The simulated location of maximal BM displacement matched the Greenwood function after tuning the BM Young’s modulus (Fig. 2). The Young’s modulus varies from 40 to 3 MPa from base to apex. This value differs from the calibrated value found in the literature [2]. This difference could arise because an unrealistic rectangular cross-sectional geometry was used in the literature. Therefore, obtaining accurate Young’s modulus needs a more realistic geometry.

A graph with a red line

Description automatically generated

Fig 2. Maximum basilar membrane deformation place versus frequency.

ACKNOWLEDGMENT

Part of the research described in this paper was performed at the Canadian Light Source, a national research facility of the University of Saskatchewan. The authors acknowledge the funding through a NSERC Discovery Grant.

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