PRELIMINARY DESIGN OF A MECHATRONIC SIMULATOR OF THE BIOMECHANICAL COUPLING BETWEEN THE EARCANAL AND THE JAW

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ABSTRACT

Given the massive spread of the hearables (wireless earphones, digital hearing protectors, hearing aids, etc.) in both our professional and personal lives, interests in improving the design of the earpiece for increased comfort and superior retention purposes have raised in recent years. Besides, with ever-increasing computing power and versatility, the battery life of such technologies remains a challenge.

Studies showed that the earcanal is deformed by the temporomandibular joint (TMJ) during daily activities such as chewing or speaking. This earcanal dynamic motion can be a promising source of power for future hearables. However, the anatomical relationship between the earcanal and the jaw is still not fully understood as in vivo measurements are complicated given the complexity of the earcanal anatomy and their associated procedures are invasive for the subjects.

The purpose of this study is hence to design and validate a mechatronic simulator reproducing the anatomical coupling between the earcanal and the TMJ. Such a device would enable the accurate assessment of the in-ear power capability for energy harvesting purpose and would also facilitate improving the earplug design for comfort and retention purposes.

The mechatronic simulator consists of modeling the TMJ and the earcanal. A six-bar linkage mechanism (6BLM) is used to mimic the trajectory of the mandibular condyle, the bony part of the jaw in contact with the earcanal surrounding tissues. Then, a 3D-printed earcanal made of silicone is designed by thickening the surface of an earmold taken in “open-mouth” position. It reproduces the earcanal cavity surrounded by elastic cartilage. The earcanal model is compressed by the mandibular condyle displacement so that the deformed cavity matches the earcanal geometry in “closed-mouth” position. A trial-and-error process using a Finite Element Model (FEM) deduces the thickness of the earcanal model at rest as well as the position of the mandibular condyle along its centroid axis. These two design variables can be optimized to represent a wider range of earcanal deformations.

An electrical motor drives the 6BLM so that it mimics the chewing frequency. A power control system guarantees the integrity of the simulator structure while deforming the earcanal model.

The mechatronic simulator is validated by comparing the geometry of the deformed earcanal model with the FEM results.

An optimized setup minimizing the root-mean-square-error for the cross-section diameter, aspect ratio and centroid axis curvature is identified. This configuration is validated as the preliminary design of a mechanical simulator of the biomechanical coupling between the earcanal and the jaw.