Bone density-based selection of optimal implantation sites for bone conduction implants.

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Objectives

When implanted in regions of denser bone, the transmission of mechanical vibration generated by bone conduction (BC) hearing implants is expected to be optimized. This study aims to validate a thickness and density-based column density index.

Materials and Methods

Quantitative CT imaging was performed in five Thiel-fixed whole head cadaver specimens. Topographic bone density maps were computed using the column density index (CODI) [1]. On every temporal bone, multiple locations characterized by different values of CODI were identified (Fig.1) and prepared to host the bone anchored hearing aid (BAHA 110 Power™, Cochlear, Australia). The 3D distance between every implantation site and the cochlear promontory (CP) was measured.

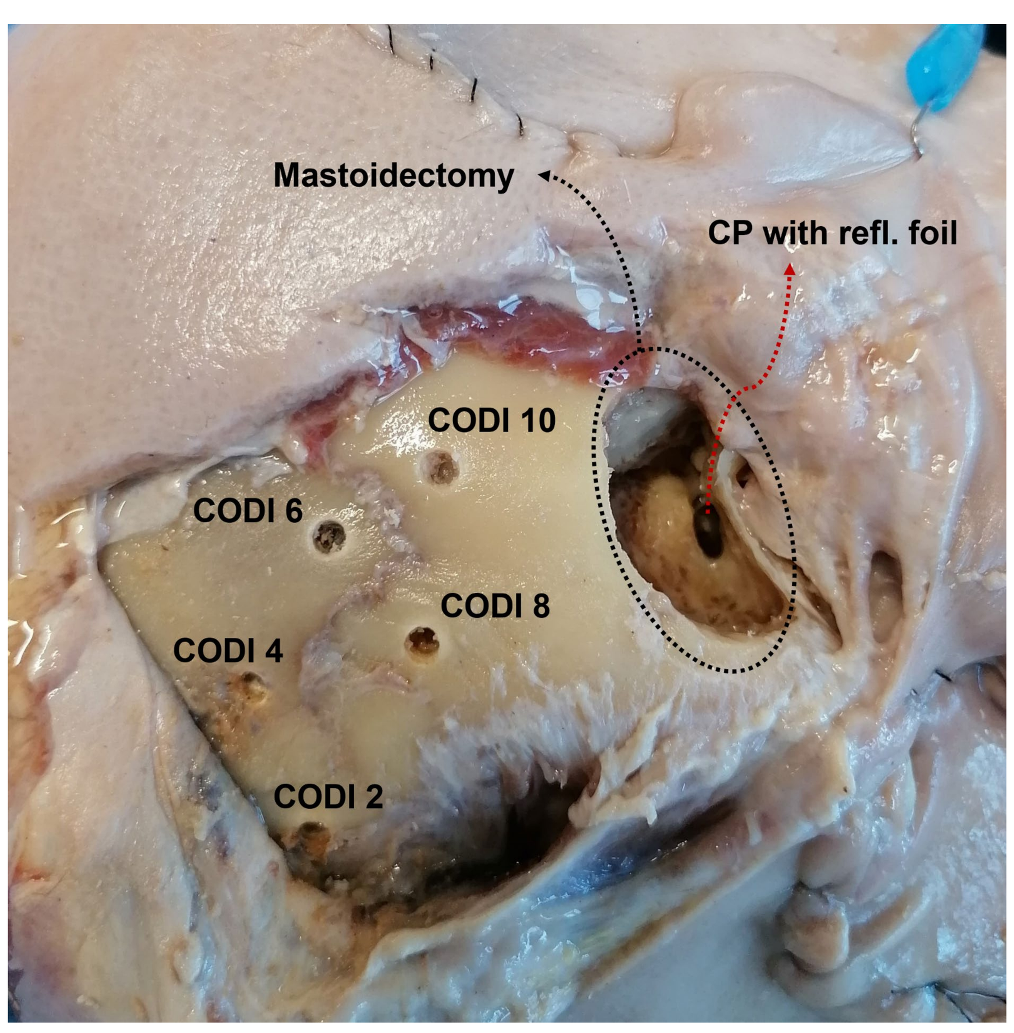

Fig. 1: Example of the different implant locations identified on one of the temporal bones. The mastoidectomy and the cochlear promontory are also visible.

Laser Doppler vibrometry was used to measure the velocity of the cochlear promontory under bone conduction stimulation with a transducer from a bone anchored hearing aid between 100 Hz and 10kHz (Fig.2). An artificial mastoid was used to measure the output force level (OFL) of the implant's transducer in order to normalize measured CP acceleration levels.

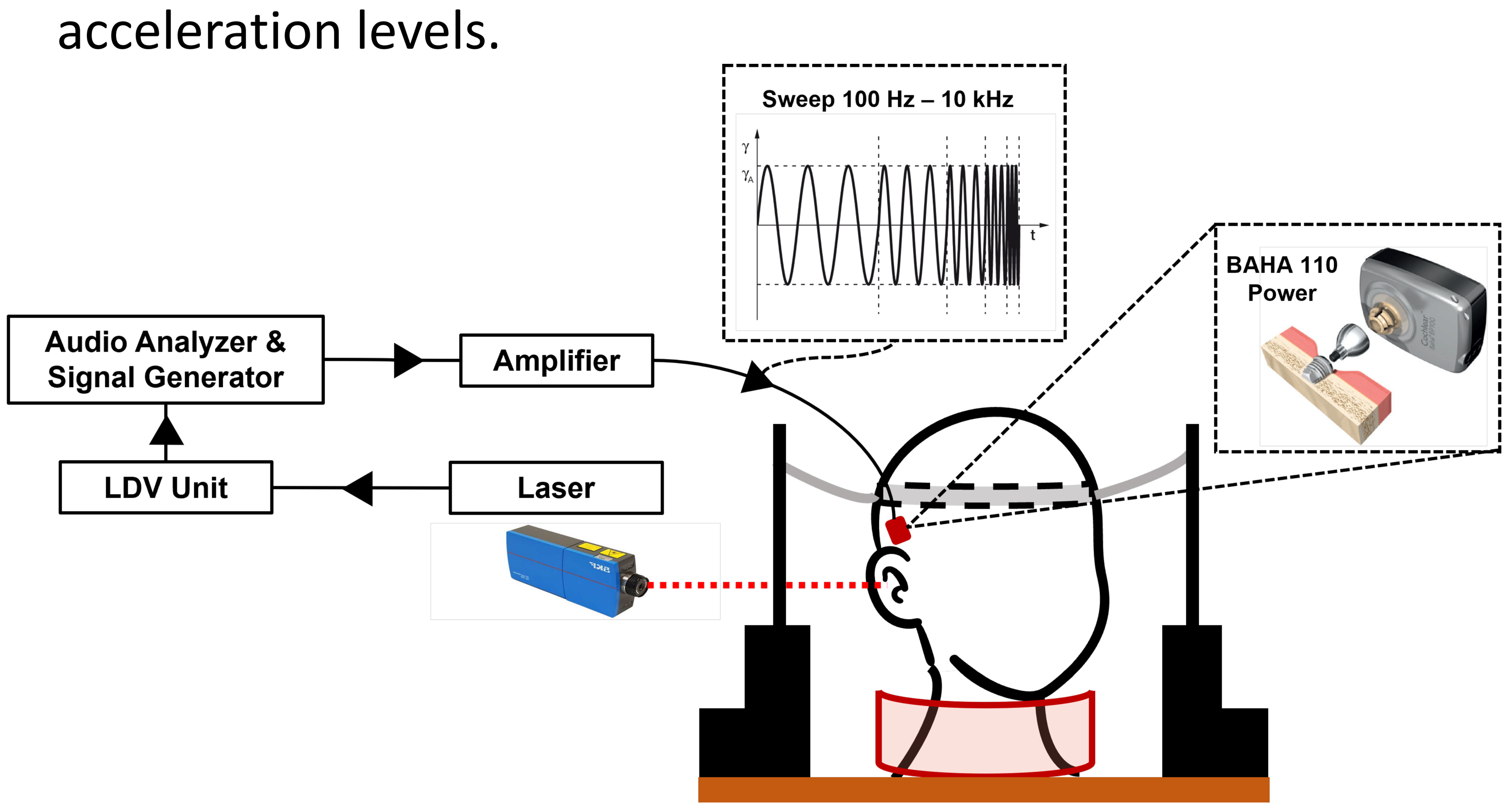

Fig. 2: Experimental set up for measuring cochlear promontory velocities. The vibrations generated by the BC implant are transmitted to the CP, which velocity is measured by the LDV. The measured signal is then processed in the audio analyzer. After the measurement, the implant is removed and placed in the next stimulation position on the bone. The head is kept in position by a pillow around the neck (in red) and two lateral support.

Results

Our obtained LDV measures were consistent with the literature [2]. The increase in normalized CP acceleration was of 0.82 dB re 1 m/s^2 N for every single increment of CODI. A significant relation between the CODI and the normalized CP acceleration was found all over the frequency spectrum.

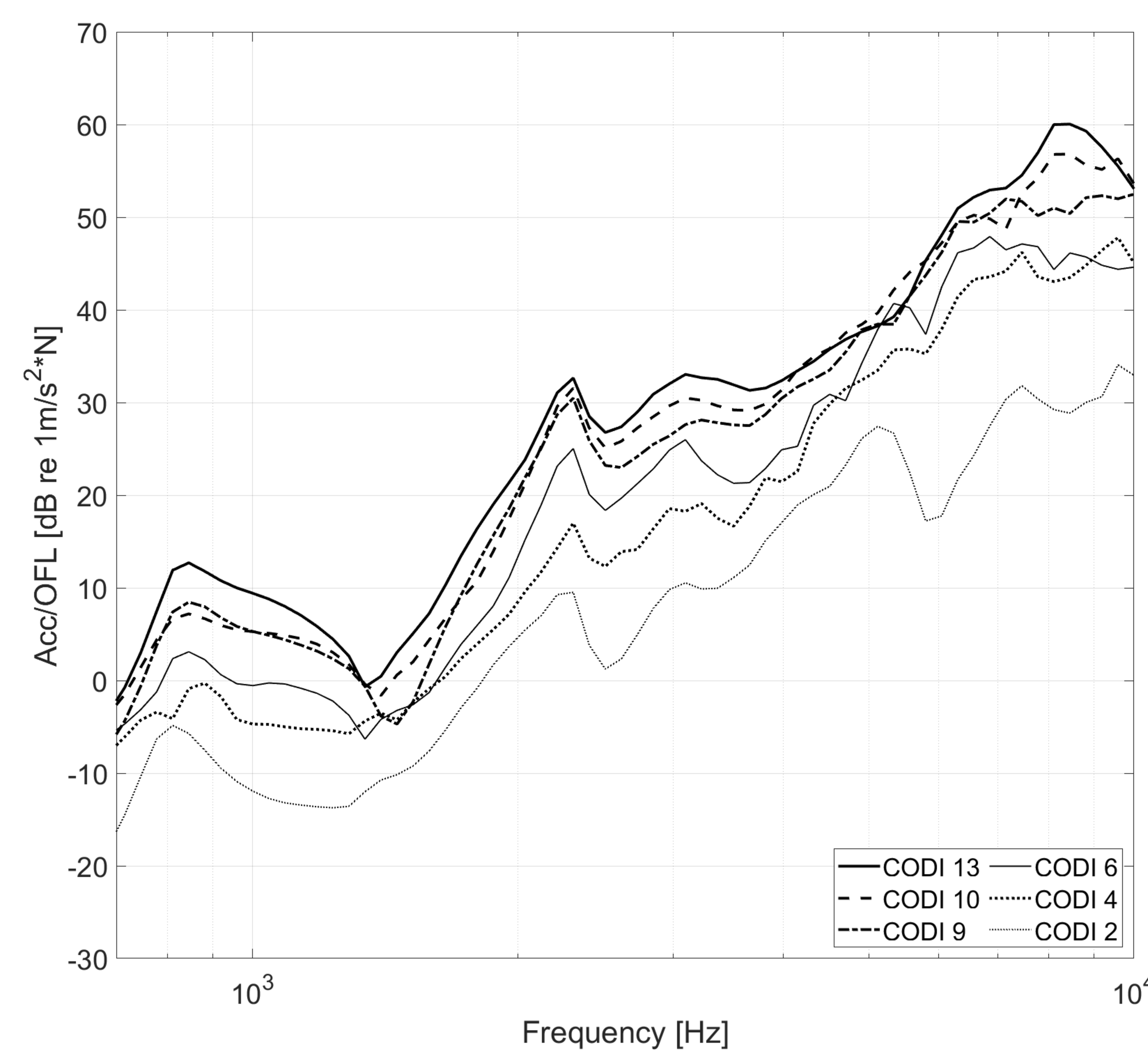

Fig. 3: Acceleration of the CP normalized with respect to the transducer force, averaged among all samples. All CODI values are expressed in $mgHA/cm^2$.

Statistic analysis showed that the distance between implantation site and CP also has significant relation with the CP acceleration levels, however, it was found that the CODI has a larger impact in variations of CP acceleration.

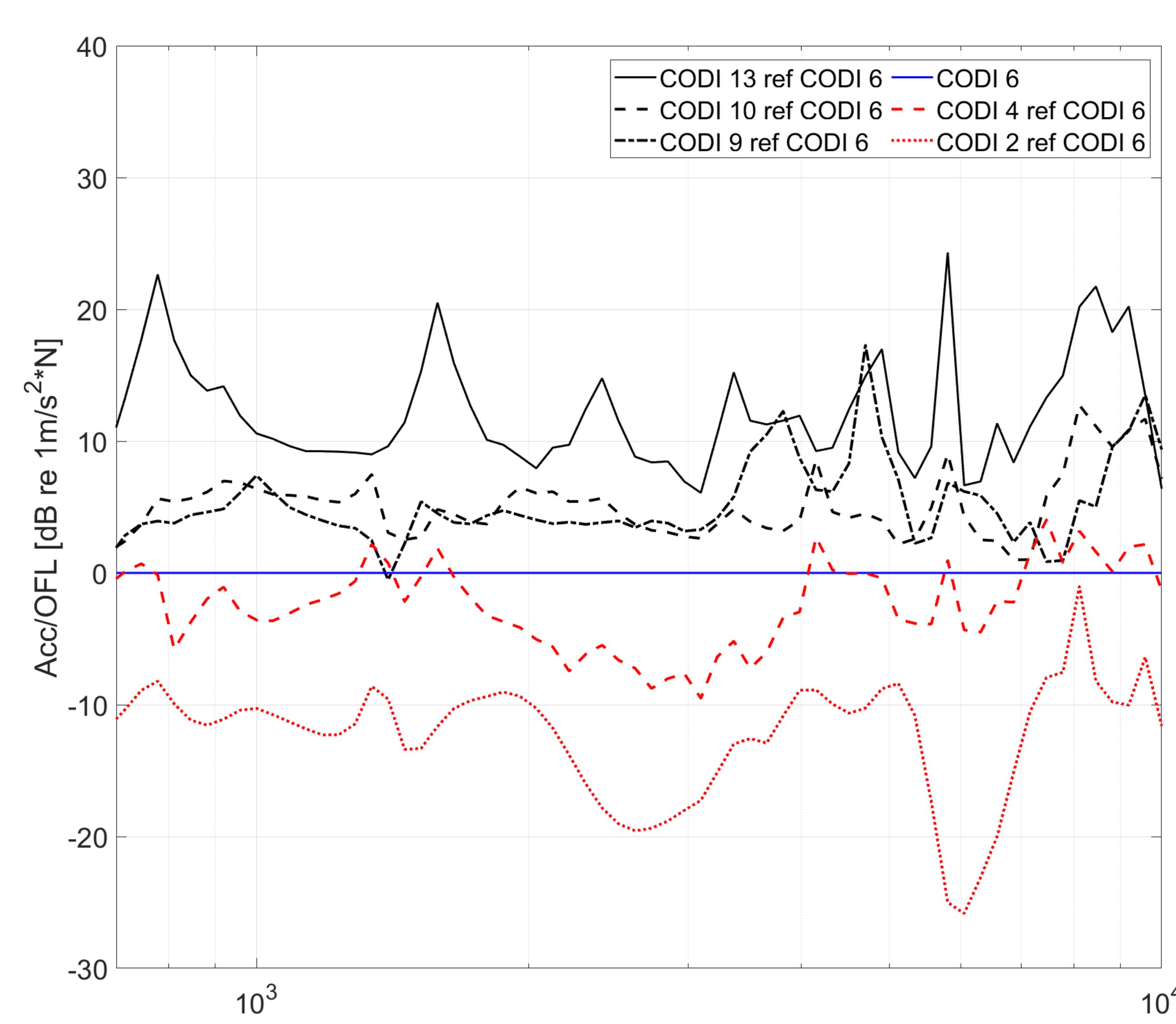

Fig. 4: Differences of the normalized acceleration levels between the different CODI values and the reference CODI of 6 (blue), averaged among the all samples. In black the CODI values higher than 6 and in red the lower ones.

Conclusions

Bone regions with higher CODI are ideal for the placement of BC implants, in order to guarantee a better transmission of mechanical vibrations to the inner ear.

References

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[2] Prodanovic, S., and Stenfelt, S. (2021). "Review of Whole Head Experimental Cochlear Promontory Vibration with Bone Conduction Stimulation and Investigation of Experimental Setup Effects", Trends in Hearing 25, 1-16

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Monte Verità, Switzerland
May 21st – 24th, 2023

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