Bone conduction stimulator position and direction investigation using numerical simulation.

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Aim: The goal of this work was to determine the amplitude of the harmonic force imposed by the bone conduction stimulator located in the temporal bone by using finite element analysis. The forces were sought that caused the same vibrations of the round window and basilar membrane as those obtained for the cochlea stimulated by the stapes. The stimulator was placed at the surface of the labyrinth capsule above the lateral semicircular canal and in the center of the anterior semicircular canal loop and at the outer surface of the squamous part.

Material and Methods: The geometrical model of the temporal bone was built using CT imaging. Over 12,000 surfaces were used to describe the bone and fluid spaces. The finite element analysis was performed in ANSYS system. The model with the excitation applied on the stapes was validated on the basis of the literature. Then a harmonic analysis for the frequency range from 0.4 to 10kHz was performed to determine the amplitude-frequency characteristics used as the reference to assess the efect of the stimulator. In the bone conduction analysis the stimulator was represented by a lumped mass. The two force amplitudes were considered which caused the amplitudes of vibration close to those obtained for the cochlea stimulated by the vibration of the stapes. The first force amplitude for bone conduction concerned the round window vibration and the second was related to the basilar membrane.

Results: For the bone conduction analysis the six directions of the harmonic force applied at the point located on the labyrinth capsule over the lateral semicircular canal were considered, assuming that the directions were available after the mastoidectomy. For the fixed stapes (otosclerosis) there was a relationship between the direction of the force and cochlear response. The force amplitudes were decreasing with the increase of frequency. The next simulation of bone conduction was performed for the stimulator placed in the center of the anterior semicircular canal loop. The four depths from 0 to 8 mm were considered assuming the fixed force direction. The force amplitudes that caused the same vibration amplitudes on the round window and basilar membrane as obtained for the cochlea stimulated by the stapes were approximately one order lover than those obtained for the stimulator situated at the reference point located at the outer surface of the squamous part. The force amplitudes decreased about twice when the point of excitation was moved to the labyrinth capsule over the lateral semicircular canal. The increase of the implantation depth caused the increase of the force amplitudes.

Conclusions: The results of FE analysis showed a significant influence of the force direction and the position and depth of the implantation on the effectiveness of the bone conduction stimulation.