Improving the Performance of Instant-Fit Earpieces by Making Use of FE-Analyses

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INTRODUCTION: Patients suffering from hearing loss can usually be provided with conventional hearing aids. In many systems, the speaker is placed in the ear canal by a soft silicone part, the so-called silicone dome. The domes are often perceived to be uncomfortable and do often have a non-reliable sealing behavior. The overall objective of this work is to develop a better understanding of the interaction between a dome and an anatomically shaped ear canal to achieve a higher wearing comfort.

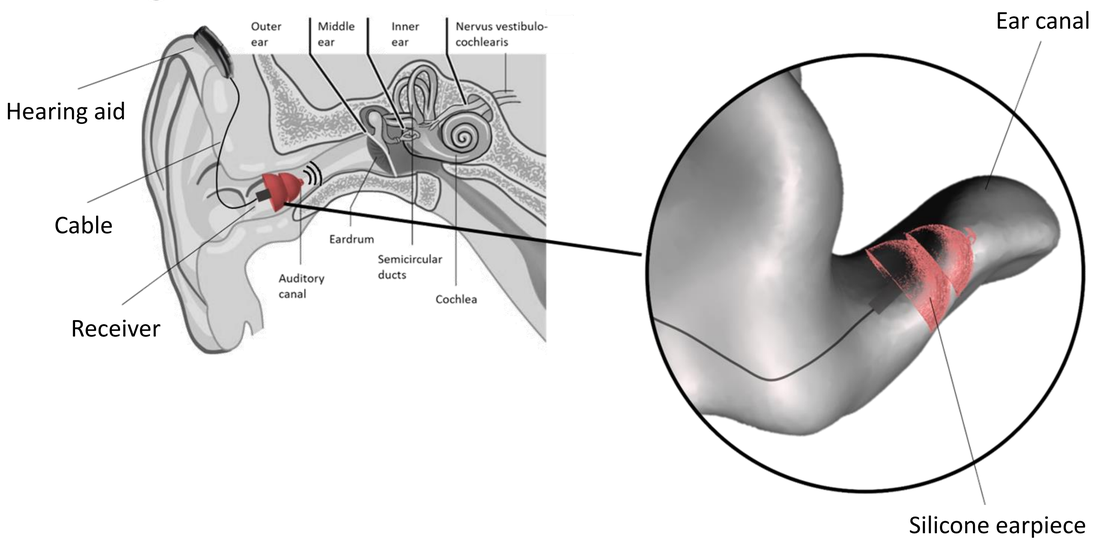

Figure 1. Schematic sectional view of an ear - edited [1]. Zoomed into a scanned ear impression with a placed silicone dome.

COMPUTATIONAL METHODS: Initially, the simulation model is built by inserting a dome into a simplified ear canal - based on a 2D rotationally axisymmetric model. The following COMSOL® interfaces are used:

Contact mechanics: Structural Mechanics Module

Material - hyperelastic material model, [2,3], Mooney-Rivlin, 5-parameters (C_{10}, C_{01}, C_{20}, C_{02}, and C_{11}).

$$P_{1_{uniaxial}} = 2(1-\lambda^{-3})(\lambda C_{10} + 2C_{20}\lambda(I_{1_{uni}}-3) + C_{11}\lambda(I_{2_{uni}}-3) + C_{01} + 2C_{02}(I_{2_{uni}}-3) + C_{11}(I_{1_{uni}}-3)$$

$$P_{1_{biaxial}} = 2(\lambda-\lambda^{-5})(C_{10} + 2C_{20}(I_{1_{bi}}-3) + C_{11}(I_{2_{bi}}-3) + \lambda^2 C_{01} + 2\lambda^2 C_{02}(I_{2_{bi}}-3) + \lambda^2 C_{11}(I_{1_{bi}}-3))$$

Prescribed Displacement - with a triangle function (/\).

Contact definition - contact pair computed with 'Augmented Lagrangian' algorithm and 'Static Coulomb Friction' (μ_{stat}).

The described material model is used for the simulation of the deformation behavior of the silicone dome in simplified shaped ear canal - shown in Fig. 2. In addition, it becomes apparent for which surfaces a contact pair is defined.

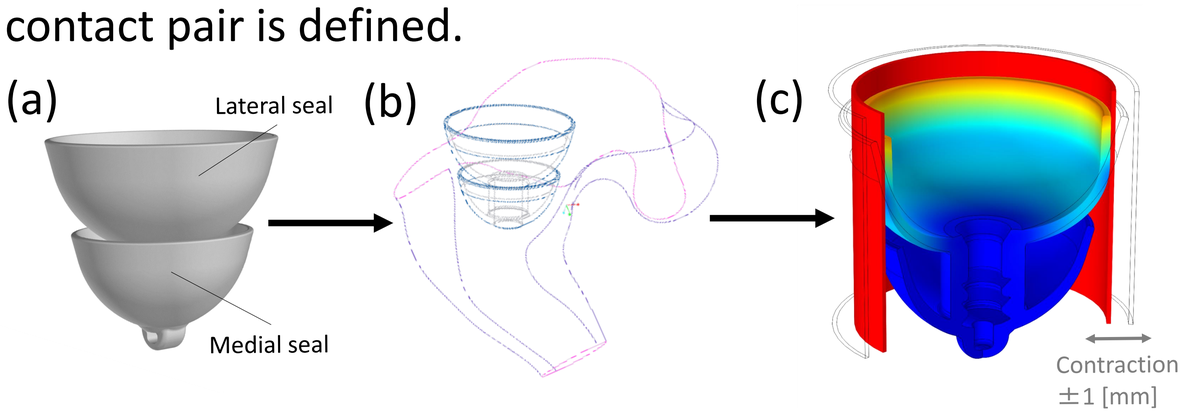

Figure 2. (a) Initial dome. (b) Edges of an anatomically shaped ear canal and a dome. (c) Compressed dome in a simplified ear canal.

RESULTS: The contact pressure distribution, for a compression of more than 10%, is shown in Fig. 3. The colored surface illustrates the contact area of the lateral seal with the inner wall of the simplified ear canal. It is apparent, that the pressure is not evenly distributed. Higher peaks are clearly visible at the upper and lower edges of the contact area a potential source of discomfort. This progression is illustrated by the diagram in Fig. 4. The averaged distribution over the remaining pressure range is steady.

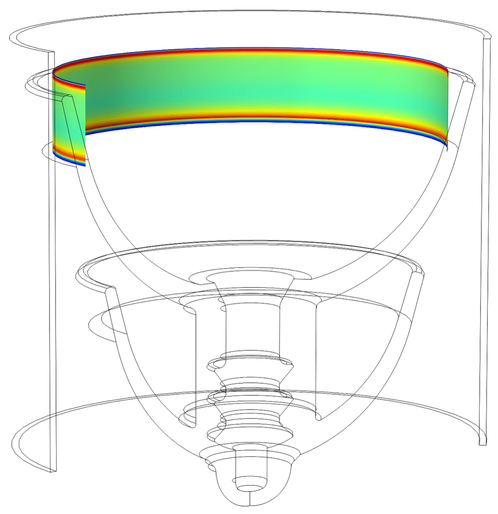

Figure 3. The sketch - initial state. The colored area shows the distribution of the contact pressure - compression > 10%.

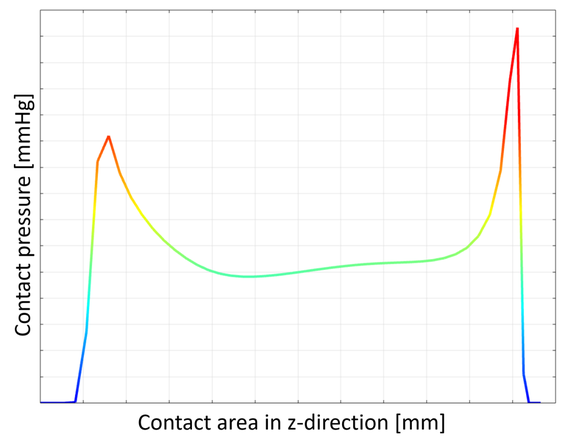

Figure 4. Curve progression of the contact pressure as a function of the contact surface.

Another important aspect influencing the wearing comfort and the sealing behavior is the circumferential stress of the lateral seal. This stress could be an indicator of whether the lateral seal starts to buckle, when the limit is exceeded.

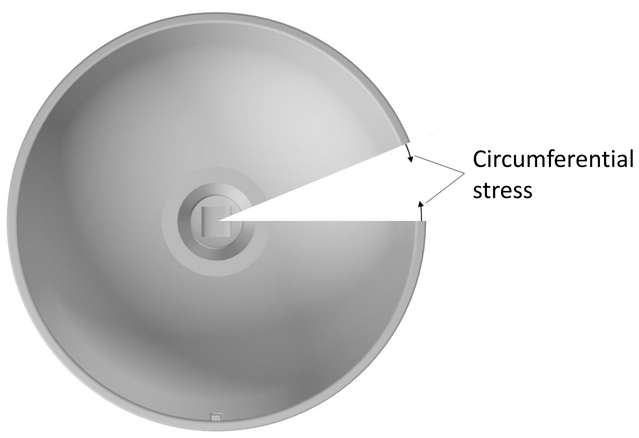

Figure 5. Top view of the lateral seal with a section for the circumferential stress.

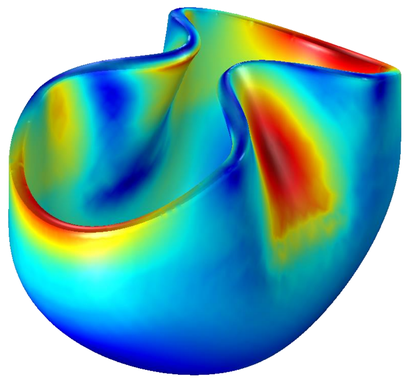

Figure 6. Buckling effect of the lateral seal.

CONCLUSIONS: With the use of simulation tools, it is feasible to analyze the interaction in terms of the deformation behavior and the exerted wall-pressure between a dome and a simplified ear canal.

OUTLOOK: In further development, the use of naturally shaped ear canals and including tissue stiffnesses will lead to a more complex and realistic simulation model.

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