A 3D FINITE ELEMENT ANALYSIS OF THE VISCOELASTIC BEHAVIOR OF THE HUMAN ORAL MUCOSA WHEN LOADED UNDER A COMPLETE DENTURE

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Introduction

A removable complete denture is supported by the residual alveolar ridges and the palate which are lined with the masticatory oral mucosa. During functional and parafunctional activities forces are applied from the denture to the mucoperiosteum, which is deformed. Linear and viscoelastic models have been suggested in the past for the deformation simulation. However, an appropriate model has not been established. The purpose of this in silico study was to examine three different models, in order to determine the one describing better the oral mucosa behaviour under loading.

Methods and Materials

A maxillary radiographic stent was fabricated by duplication of a removable complete which was made for a young edentulous patient. The stent was made from clear PMMA resin. The tissue surface of the stent was modified by grinding two rectangular 8 x 10 x 3 mm areas on each side and lining these areas with 0.5 mm thickness of Sn. The rest of the tissue surface of the stent was not modified. In this way the unmodified areas loaded the oral mucosa, while the modified areas did not exert any pressure on the mucosa. A CBCT scan was made for the maxilla while the patient was biting with maximum force. The radiographical images were processed by a special software (Mimics 10.01) and a highly accurate 3D model of the maxillary anatomy was modelled. The data were then incorporated to a finite element analysis software (Ansys 14.5) in order to test the behaviour of the oral mucosa when it is loaded. The displacement of the mucosa on the residual maxillary ridge was tested in a previous experimental in vitro project (IADR meeting, Seattle, 2013) with the use of AFM and specimens harvested from a frozen elderly human cadaver. A nonlinear constitutive model was obtained and enabled a simulation of the oral mucosa behavior by FEM. The load-displacement data obtained from this project were then converted into stress-strain data in order to be used in the FEA. Linear, viscoelastic and 3rd degree polynomial models were tested.

Results

The results of the present study suggest that the deformation of the oral mucosa can be simulated with both the viscoelastic and the 3rd degree polynomial model. Among the three tested models the best results were supplied with the 3rd degree polynomial model. The results of the simulation were influenced by the limiting conditions. Maximum total deformation was found to be 1.6mm/100N and directional deformation was 0.4mm. Significant deviations were evident when the linear model was used, with unrealistic total deformations of 8.8mm/500N.

Discussion/Conclusion

The results of the present study suggest that the linear model should not be used. Although the viscoelastic model can be used, the 3rd degree polynomial model seems to be the most appropriate for explaining the behavior of the oral mucosa under load.

References

1. Sawada A et al. Vicoelasticity of human oral mucosa: implications for masticatory biomechanics, J Dent Res 2011;90:590-5
2. Lacoste-Ferre MH et al. Dynamic mechanical properties of oral mucosa: Comparison with polymeric soft denture liners. J Mech Behav Biomed Mater 2011;4:269-74
3. Kanbara R et al. Three-dimensional finite element stress analysis: the technique and methodology of non-linear property and soft tissue loading behaviour for different partial denture designs. J Dent Mater 2012;31:297-308