Biomechanical Evaluation of a Metal Polymeric Fixed Partial Prosthesis with Different Periodontal Support

MARIUS MANOLE[1], COSMIN SINESCU[2], MEDA-LAVINIA NEGRUTIU[2], LAVINIA ARDELEAN[2], DIANA DUDEA[1], MIHAI ROMINU[2]
[1]University of Medicine and Pharmacy Iuliu Hatieganu from Cluj Napoca, Faculty of Dentistry, 8 Victor Babes Str., 400023, Cluj, Romania
[2]University of Medicine and Pharmacy Victor Babes from Timisoara, Faculty of Dentistry, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania, Romania

A non invasive method as numerical simulation was employed to evaluate the periodontium comportment under the occlusal force appliances. Three types of periodontal support for a three elements metal polymeric fixed partial prosthesis were considered. The retractions trends of the periodontium were correlated with the occlusal conditions.

Keywords: metal - polymeric fixed partial prosthesis, numerical simulation, periodontium

Lihe Qian investigated the full-field distributions of displacement, stress and strain, and their evolution with loading in the entire fresh periodontium under an externally applied force. In situ intrusion tests were performed to identify the nonlinear, viscoelastic behavior of the periodontal ligament (PDL) of a pig mandible; a digital image correlation method was applied to examine the full-field deformation patterns in the entire periodontium. The finite element (FE) model was created based on the actual anatomic profiles of individual constituents of the tooth structure; the nonlinear and time-dependent viscoelastic properties of the PDL were input into the FE model to fit the numerical computations with the experimental measurements. The nonlinear, viscoelastic behavior of the PDL was identified and characterized quantitatively. The simulation results were validated by the experiments. The results showed the tilting of tooth and the movement of cervical bone toward the mid-tooth in the studied periodontium under vertical compressive loading. Major strain was concentrated in the PDL, with the maxima near to the tooth apexes, at the tooth-root bifurcation and also at the sides of the tooth roots, and maintained a slight rise during holding of the applied displacement. High stress in the tooth was located mainly at the sides of tooth roots, in the bone it was concentrated near the apexes and the root bifurcation, and these stresses decreased gradually during the holding period. The combined approach of experiments that apply the digital image correlation method and FE analyses that take into account the nonlinear and time-dependent viscoelasticity of the PDL enables the acquisition of a full picture of detailed, realistic stress/strain fields and deformation patterns of the entire fresh periodontium, being of essence in orthodontics and dentistry [1].

Ted S. Fill highlighted and discussed discrepancies in the literature of the periodontal ligament's (PDL) mechanical properties and the various analytical models, approaches and assumptions used in simulating its behavior. His study then offers to propose a model development that allows for a better phenomenological description of PDL behavior under static, near clinical, orthodontic loading conditions [2].

Kristina Möllers studied the inlay-retained fixed partial dentures, as a conservative prosthetic restorations. Their failure resistance is influenced by the stress distribution that depends on the material properties as well as the loading conditions. Finite element analysis provides the ability to estimate the loading capacity by simulating the stress distribution in all-ceramic dental restorations. The null-hypothesis of the study was that tooth mobility or tooth bearing condition significantly influences the stress distribution and therefore the failure resistance of all-ceramic inlay-retained fixed dental prostheses. Therefore, the stress distribution under different loading and bearing conditions of the teeth was analyzed using the finite element method. Three different bearing conditions, one fixed and two flexible were chosen to simulate tooth mobility. The flexible models were constrained with spring elements to a virtual center of rotation. In addition, loading conditions were varied. The influence of tooth mobility on the stress distribution depended on the degree of modeled tooth mobility, as well as the loading conditions. The maximum first principal stresses differed significantly in magnitude and location depending on the modeled bearing condition and the simulated load case. The maximum difference between fixed and flexible model was more than 100%. Tooth mobility and occlusal loading conditions have to be considered in finite element analyses as the simulated stress distribution is strongly influenced by these factors [3,4].

Experimental part

A metal polymeric fixed partial prosthesis with 3 elements was considered (from 1.6. to 1.4.). The model was obtained by MicroScribe technology. With the MicroScribe G2 Desktop Digitizing System was trace over the contours of the analogical Frasaco dental model with a metal polymeric fixed partial prosthesis positioned from 1.4. to 1.6. The obtained contours were used to generate a 3D solid of the fixed partial prosthesis, teeth and the periodontal tissue with the bone associated. The volume obtained (12730 mm^3) contained 94375 nodes and 52874 elements after the discretisation procedure (fig. 1). The model was considered fixed at the bone level and a force of 250 N was applied on each element of the fixed partial prosthesis (fig. 2). Another two situations were considered when the periodontal and bone support were reduced with 25% and with 50% in entire structure (fig. 3, 4). The numerical simulation was performed and the results were presented.

* email: meda_negrutiu@yahoo.com

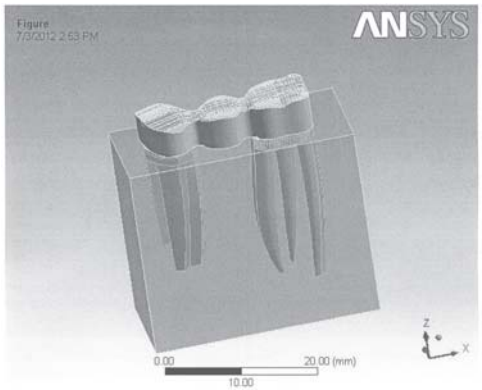

Fig. 1. The aspect of the considered model for this study

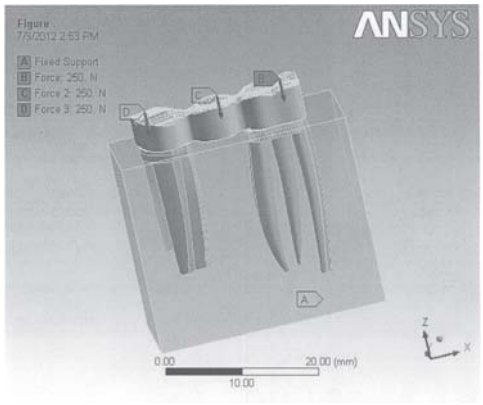

Fig. 2. The aspect of the applied forces on the structure

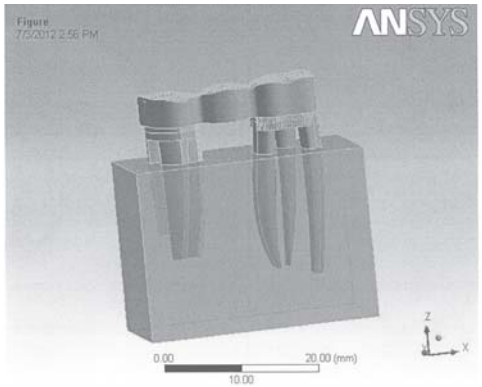

Fig. 3. The model with 25 % periodontal and associated bone retraction considered in this study

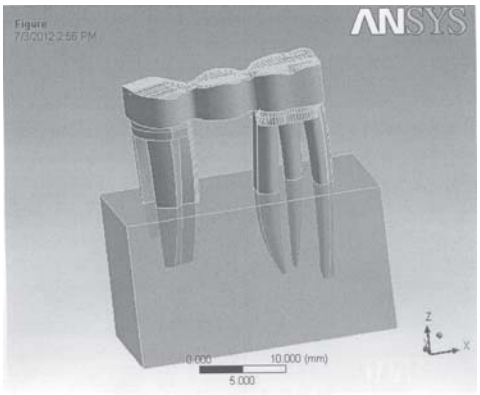

Fig. 4. The model with 50 % periodontal and associated bone retraction considered in this study

Results and discussions

After the numerical simulation was performed for all 3 considered situation, the equivalent von Mises Stress, total deformation, frictional stress at the periodontal level and periodontal deformation charts were presented (fig. 5-7).

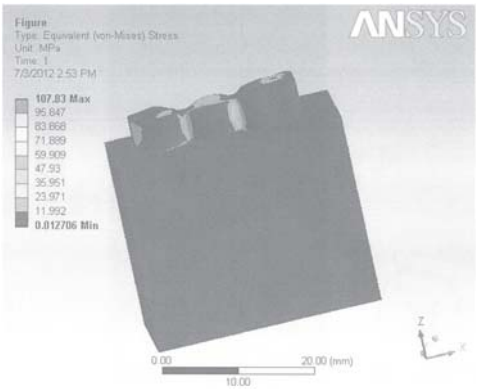

Fig. 5. The equivalent von Mises Stress chart for the first considered model

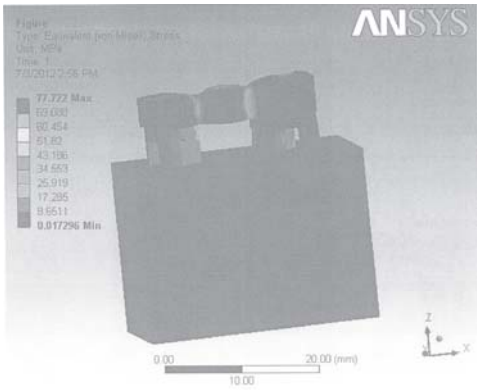

Fig.. 6. The equivalent von Mises Stress chart for the 25 % periodontal retraction model

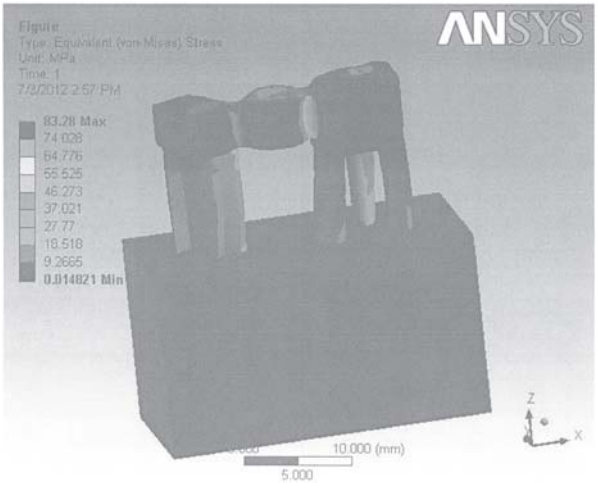

Fig.. 7. The equivalent von Mises Stress chart for the 50 % periodontal retraction model

For all the considered samples the maximum tensions were observed in the metal polymer fixed partial prosthesis. Due to the material resistance of the dental alloy (Co-Cr) these tensions will not affect the prosthesis integrity.

From the charts of frictional stress results that the stress is increasing from the first situation (1 MPa) almost five times (5.6622 MPa) in the case of 25 % periodontal retraction and almost eight times (8.2219 MPa) in the case of 50 % periodontal retraction. It is important to mention that this increasing stress is delivered to a bone and roots structure that decreases in the second and in the third considered cases. Also a four time in the second case and five time increasing could be spotted from the charts of sliding and penetrations of the roots in the bone structure.

The pressure charts reveal the fact that the pressure in the periodontal tissue is increasing along with the decrease of the periodontal support of the roots.

Conclusions

In conclusion, noninvasive evaluations methods, like numerical simulation, could give a good estimation of the influence of the occlusal forces to the periodontal support. Along with the decreasing of the periodontal support the tensions in these areas is increasing being reported to a decreasing structure.

Acknowledgement: This paper was supported by the project nr. 101, CNCSIS grant of the Ministry of Education in Romania,.

References

1. LIHE QIAN, MITSUGU TODO, YASUYUKI MORITA, YASUYUKI MATSUSHITA, KIYOSHI KOYANO, Deformation analysis of the periodontium considering the viscoelasticity of the periodontal ligament, Dental Materials, Volume 25, Issue 10, October 2009, Pages 1285-1292, ISSN 0109-5641, 10.1016/J.DENTAL.2009.03.014.

2. TED S. FILL, ROGER W. TOOGOOD, PAUL W. MAJOR, JASON P. CAREY, Analytically determined mechanical properties of, and models for the periodontal ligament: Critical review of literature, Journal of Biomechanics, Volume 45, Issue 1, 3 January 2012, Pages 9-16, ISSN 0021-9290, 10.1016/j.jbiomech.2011.09.020.

3. KRISTINA MÖLLERS, DANIEL PARKOT, ARMIN KIRSTEN, JAN-FREDERIK GÜTH, DANIEL EDELHOFF, HORST FISCHER, Influence of tooth mobility on critical stresses in all-ceramic inlay-retained fixed dental prostheses: A finite element study, Dental Materials, Volume 28, Issue 2, February 2012, Pages 146-151, ISSN 0109-5641, 10.1016/j.dental.2011.10.013.

4. COSMIN SINESCU, MEDA LAVINIA NEGRUTIU, CARMEN TODEA, COSMIN BALABUC, LAURA FILIP, AND ROXANA ROMINU, ADRIAN BRADU, MICHAEL HUGHES, AND ADRIAN GH. PODOLEANU, Quality assessment of dental treatments using enface optical coherence tomography, J. Biomed. Opt., Vol. 13, 2008; 054 - 065

Manuscript received:1.08.2012