Preliminary Studies on the Biomechanical Behavior of Metal-ceramic Restorations

LAURENTIU DRAGUS[1,2], ALBERTA SIMONA TINU[1], COSTIN COMAN[1], RALUCA MONICA COMANEANU[1]*, DOINA LUCIA GHERGIC[1]

[1] Titu Maiorescu University of Bucharest, Faculty of Dental Medicine, Gh. Petrascu, 67A, Bucharest, Romania

[2] Dunarea de Jos University of Galati, Faculty of Medicine and Farmacy, 35 Al. I. Cuza Str., 800010, Galati, Romania

In order to increase the patient's quality of life, interdisciplinary studies on dental materials are becoming more and more frequent in an attempt to assess as accurately as possible the resistance of dental restorations over time. One of the methods of analysis of resistance to the masticatory forces of dental restorations is the finite element method (FEM). We studied a 3-element dental bridge made of a metallic Co-Cr-Mo alloy and dental ceramics, designed for the prosthesis of a tooth 3.6. On each element of the dental bridge we applied a force of 250 N in the direction Z and a force of 100 N in the Y direction. The most vulnerable areas, where the highest stresses occur, are located predominantly in the neck regions and around the points of contact between the elements of the dental bridge. However, the experimentally determined values have low intensities that would not endanger the resistance of the restoration unless it is overloaded.

Keywords: FEA, masticatory forces, dental bridge, metal-ceramic restoration

Mixed metal-ceramic fixed prosthetic restorations have been considered for more than 50 years the *gold standard* for the rehabilitation of edentulous due to the aesthetics offered, the mechanical characteristics of the prosthetic parts and their superior adaptation [1-5] to the dentures and / or implants.

In order to increase the quality of life of patients, interdisciplinary studies on dental materials are becoming more and more frequent in attempting to assess as accurately as possible the resistance of dental restorations over time.

One of the methods of analysis of resistance to the masticatory forces of dental restorations is the finite element method [6-9].

Experimental part

We have studied a 3-element dental bridge made of Co-Cr-Mo metal alloy and dental ceramics made for the prosthesis of a tooth 3.6. The 3D layout in the STL format of the future prosthetic piece was discretized with the soft 3 -matic © Materialise NV, and numerical analyzes were performed with ANSYS © SAS IP, Inc. The properties of the materials used in making the prosthetic piece were taken from the MatWeb site (www.matweb.com) (table 1).

Table 1

PROPERTIES OF MATERIALS USED TO MAKE RESTORATION

	Density kg m^{-3}	Young Module MPa	Poisson Coefficient -
Alloy	8.8	2.0×10^{5}	0.3
Ceramics	3.9	3.4×10^{5}	0.22

On each element of dental bridge we applied a force of 250 N in the Z direction and a force of 100 N in the Y direction, resulting in a force of 223.61 N on 3.5 crown, a 269.26 N force on the 3.6, and also a 269.26 N force on 3.7 crown.

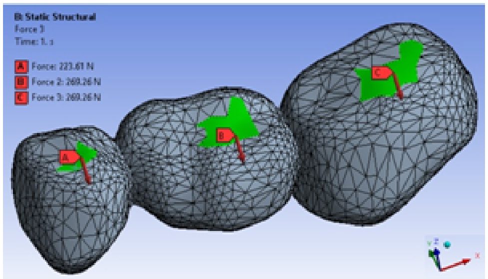

Fig. 1.Contact surfaces and applied forces

Results and discussions

The Von Mises equivalent stresses are stretching tensions and varied between 1.4e4 Pa (recorded at neck of 3.7 crown) and 1.1e8 Pa (at the contact point between 3.6 and 3.7).

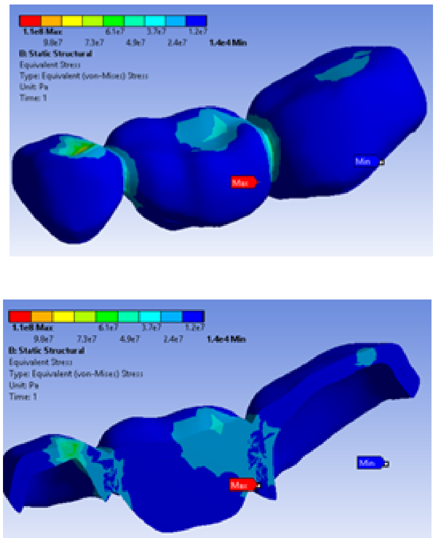

Fig. 2. Equivalent tensions (von Mises) on the surface of the restoration and on the section

Normal tensions were compression tensions on the surface of the restoration, but in the crown section they become stretching. The maximum bending effect is between the molar 1 and the molar 2 on the neck.

Horizontal shear stresses (XY) were compression in the zones of force application and stretch to the point of contact between molar 1 and molar 2, especially to the neck where is located the maximum value. The maximum shear stress

*email: monica_tarcolea@yahoo.co.uk; Phone: 0723860069

All authors have equal contributions to the study

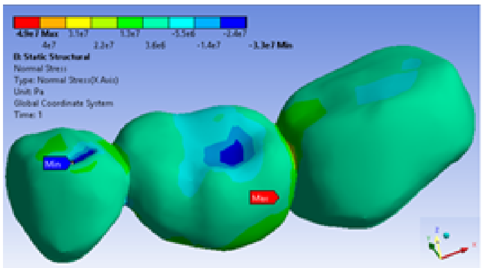

Fig. 3.Normal tensions

values in XZ were stretched, mainly located at the buccal zone, but in the areas of force application there were compression stresses.

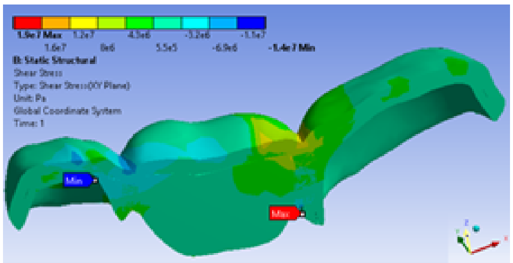

Fig. 4. Shear stress on the restoration area in the XY plane

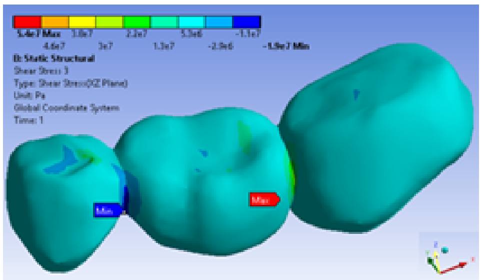

Fig. 5. Shear stress on the surface of the restoration in the XZ plane

Minimum shear stresses in the XZ plane occur at the junction between the premolar 2 and the molar 1. In the rest of the restoration the tensions are stretching, with maximum value at contact between M1 and M2, on the neck.

The total deformation had positive values, and the maximum values are reported in the 3.6 element, especially to the buccal zone.

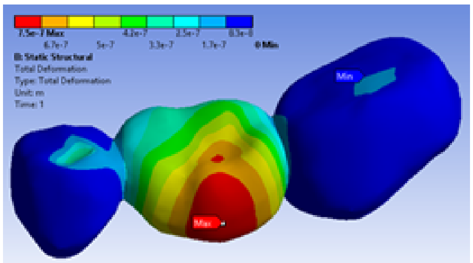

Fig. 6. Total deformation

The normal elastic strain in the X direction is elongation, with maximum values on the inner face of the crown on the premolar and at the point of contact between the molars. The normal elastic strain in the Y direction varied between -0.00012612 m / m and 9.3862e-5 m / m. There are stretches with maximum values in the areas where the force was applied to the crowns 3.5 and 3.6, and to the points of contact between the crowns the values change the sign (become compressions) as well as on the mucosal surface of the 3.6 element.

In the direction Z, compressions occur at the points in which is applied the experimental forces and stretches occur with very low values in the rest of the dental bridge.

The shear elastic strain in the XY plane varied between -0.00011 m / m and 0.0002 m / m. Compression occurs on 3.5 and 3.6 elements on the areas in which are applied experimental forces, as well as at the point of contact

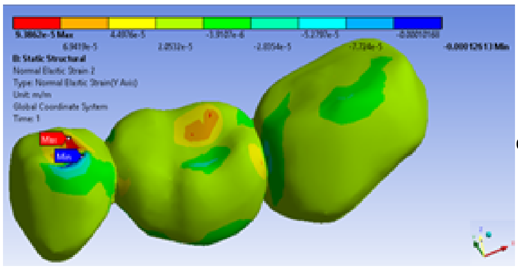

Fig. 7. The normal elastic strain in the Y direction

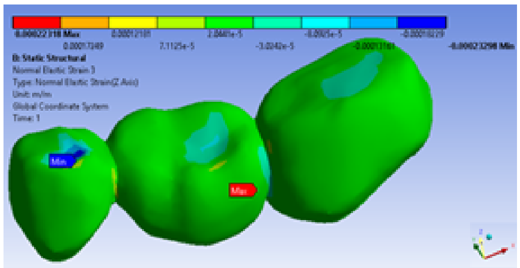

Fig. 8. The normal elastic strain in the Z direction

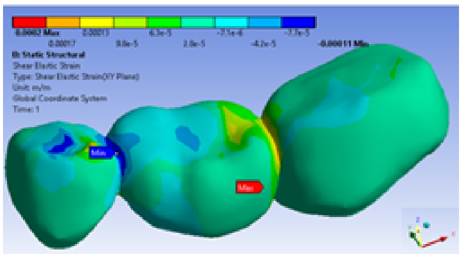

Fig. 9.The shear elastic strain in the XY plane

between 3.5 and 3.6, while at the contact point between 3.6 and 3.7 is elongations.

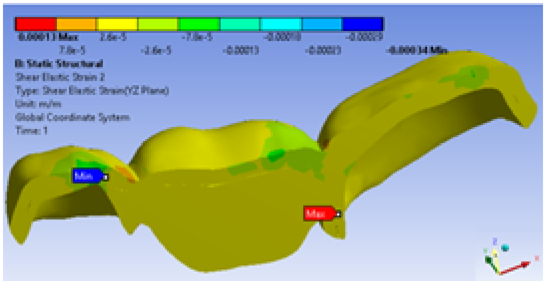

Fig. 10. The shear elastic strain in the YZ plane

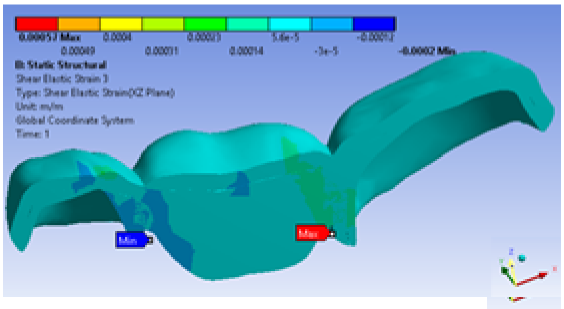

Fig. 11.The shear elastic strain in the XZ plane

The shear elastic strain in YZ plane had isolated areas of compressions and stretches at the point of contact between the bridge elements.

Analyzing the shear elastic strain in the XZ plane, we found that small compressions occur at the zone of the application of the experimental forces and at the junction between 3.5 and 3.6 elements.

The literature reports on the incisor group average forces of 200-300 N [10], but in most experimental analyzes the value of occlusal loading considered is 50 N [11].

The results obtained from the finite element analyzes depend on the value of the experimental force applied to the tooth [11], the distribution of the occlusal forces on the dental slopes and the direction of application [7, 12].

The finite element method [13, 14] allows the optimal configuration of biomechanical dental restorations as well as the direct transfer of experimental results to future prosthetic rehabilitation.

Conclusions

The most vulnerable areas, where the highest stresses occur, are located predominantly in the neck regions and around the points of contact between the elements of the dental bridge. However, the experimentally determined values have low intensities that would not endanger the resistance of the restoration unless it is overloaded.

References

1.HEFFERNAN MJ, AQUILINO SA, DIAZ-ARNOLD AM, HASELTON DR, STANFORD CM, VARGAS MA. Relative translucency of six all-ceramic systems. Part 1: core materials. J Prosthet Dent 2002;88:4-9.

2.PJETURSSON BE, SAILER I, ZWAHLEN M, HAMMERLE CH. A systematic review of the survival and complication rates of all-ceramic and metal–ceramic reconstructions after an observation period of at least 3 years. Part I: single crowns. Clin Oral Implants Res 2007;18(Suppl. 3):73-85.

3.REITEMEIER B, HANSEL K, KASTNER C, WALTER MH. Metal–ceramic failure in noble metal crowns: 7-year results of a prospective clinical trial in private practices. Int J Prosthodont 2006;19:397-9.

4.SAILER I, PJETURSSON BE, ZWAHLEN M, HAMMERLE CH. A systematic review of the survival and complication rates of all-ceramic and metal–ceramic reconstructions after an observation period of at least 3 years. Part II: fixed dental prostheses. Clin Oral Implants Res 2007;18(Suppl. 3):86-96.

5.WETTSTEIN F, SAILER I, ROOS M, HÄMMERLE CH. Clinical study of the internal gaps of zirconia and metal frameworks for fixed partial dentures. Eur J Oral Sci 2008; 116:272–9.

6.MOLLERS K., PATZOLD W., PARKOT D., KIRSTEN A., GUTH J.F., EDELHOFF D., FISCHER H., Influence of connector design and material composition andveneering on the stress distribution of all-ceramic fixed dental prostheses: A finite element study, Dent. Mater, 2011, 27, e171-75.

7.MUDZKI J, CHLADEK G, KASPERSKI J, DOBRZANSKI LA., One versus two implant-retained dentures: comparing biomechanics under oblique mastication forces, J. Biomech. Eng., 2013, 135(5), DOI, 10.1115/ 1.4023985.

8.MOLLERS K., PATZOLD W., PARKOT D., KIRSTEN A., GUTH J.F., EDELHOFF D., FISCHER H., Influence of connector design and material composition andveneering on the stress distribution of all-ceramic fixed dental prostheses: A finite element study, Dent. Mater, 2011, 27, e171-e175.

9.MUDZKI J, CHLADEK G, KASPERSKI J, DOBRZANSKI LA., One versus two implant-retained dentures: comparing biomechanics under oblique mastication forces, J. Biomech. Eng., 2013, 135(5), DOI, 10.1115/ 1.4023985.

10.CHLADEK W., Biomechanika in¿ynierska narz¹du ¿ucia. Zagadnienia wybrane, Wydawnictwo Politechniki Slaskiej, Gliwice 2008.

11.SAKAGUCHI R.L., POWERS J.M., Craigs Restorative Dental Materials, Elsevier, 2012.

12.CORREIA A.R.M., FERNANDES J.C.S., CAMPOS J.C.R., VAZ M.A.P., RAMOS N.V.M., Stress analysis of cantilever fixed partial denture connector design using the finite element method, Rev. Odonto Cienc., 2009, 24(4), 420-425.

13.COMAN C, GHERGIC DL, PATROI DN, TARCOLEA M, COMANEANU RM, BARBU HM, Comparative Assessment of Resistance Against Experimental Forces of Mixed Prosthetic Restorations, Mat. Plast., **53**, no. 1, 2016, p. 91.

14.STAMATE A, VLASCEANU D, MARGARIT R, LUCA R, CARAIANE A, 3D Analysis of the Accumulated Stresses in a Premolar Restored with a Composite Inlay versus a Ceramic Inlay, Mat. Plast., **51**, no. 3, 2014, p. 286.

Manuscript received: 11.02.2018