SOME MECHANICAL CHARACTERISTICS OF MATERIALS FOR DENTAL PROSTHETICS

Diana Cotoros, Anca Stanciu and Mihaela Baritz
Department of Product Design, Mechatronics and Environment
Transilvania University of Brasov
500036, Brasov, Romania
E-mail: dcotoros@unitbv.ro, ancastanciu77@yahoo.com, mbaritz@unitbv.ro

KEYWORDS
Molar modelling, finite element method, mechanical characteristics.

ABSTRACT

The paper presents some researches concerning the mechanical properties of composite materials used for prosthetic dental elements. After a short introduction concerning the general strains and loads that usually apply upon prosthetic works, the authors present the virtual model of a molar tooth subjected to the most common actions, using finite element method. Then the results are further shown by means of experimental methods and finally the conclusion concerning the possible use of fibre reinforced composite materials are presented.

INTRODUCTION

One of the most pressing issues concerning dental health is related to the use of materials for prosthetics and implant jobs. These materials should be suitable not only from the biocompatibility point of view but also their mechanical properties should be at least similar to those of the natural dentition, let alone the fact that we still need to meet the aesthetics requirements.
Prosthetic works either mobile or constructed upon an implant structure should be able to resist to all kind of loads and strains of various types, starting with mechanical actions, chemical attacks or temperature variation.
Usually the materials are included in the metal-acrylate or metal-ceramics family, each with corresponding benefits and risks. Roughly, we may say that metal-ceramics (with porcelain antagonists) are mostly preferred today due to their structure rigidity while acrylic works present the advantage of a better shock damping, but they are not resistant enough.
Another serious candidate seem to be fibre reinforced composite materials, including different types of fabric, like weft or warp fabric, each offering additional properties.
Of course, prosthetic works should be covered generally with porcelain or noble metals crowning and require extended preparations. These covers will protect at a certain extent the surface from chemical agents and moderate temperature variations, even from some types of mechanical actions. But still there is an obvious necessity that the prosthetic structure resists to the real mechanical strains involved in the everyday mastication process and also to some imperfections due to the lack of symmetry in antagonist teeth during occlusion.
The investigations done upon the occlusion forces clearly showed that the average bite force of a patient may reach 665N in molars and up to 220N in incisive teeth. Generally the bite force of women is a little smaller than the one applied by males.

FINITE ELEMENT METHOD APPLIED FOR A MOLAR MODELLING

Generally, the finite element method is the most suitable to predict the analysis parameters and the tendencies of the analyzed item.
There are several information to consider in order to determine the stress and deformations by help of finite elements method, like:
- number of nodes and discretization elements
- a numbering system required to identify every node and element
- elasticity modulus E and Poisson’s coefficient for the materials associated to each element
- coordinates of every node
- type of constraints and boundary conditions
- values of forces applied in external nodes

The first step is simulating the 3D model of the molar using a virtual representation software, like CATIA V5 and the results were imported in the finite element software ABAQUS.
But still we needed to consider the fact that not always the teeth are symmetrically located, therefore during dental occlusion the compression force is very likely to act in an eccentric position, overloading only a certain part of the tooth. So the interaction between antagonist teeth might look like in fig.1.

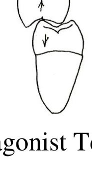

Figure 1 Antagonist Teeth Interaction

Proceedings 26th European Conference on Modelling and Simulation ©ECMS Klaus G. Troitzsch, Michael Möhring, Ulf Lotzmann (Editors)
ISBN: 978-0-9564944-4-3 / ISBN: 978-0-9564944-5-0 (CD)

This is why it was necessary to consider two types of loads upon the composite material molar model: centric compression and eccentric compression using forces compatible to the normal human bite force.
If the load is applied at the center of the molar, which is an ideal situation, corresponding to a perfect symmetry of the anagonist teeth during occlusion, the values and distribution of the principal stress is shown in figure 2.

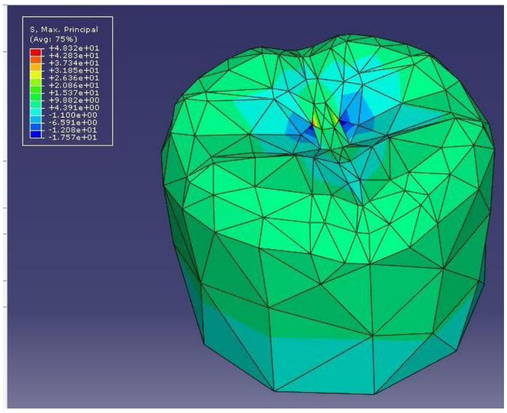

Figure 2: Principal Stress Distribution for a Centric Compression

For the second situation, which is also more encountered due to the imperfections in the occlusion of antagonist teeth, the principal stress distribution is presented in figure 3.

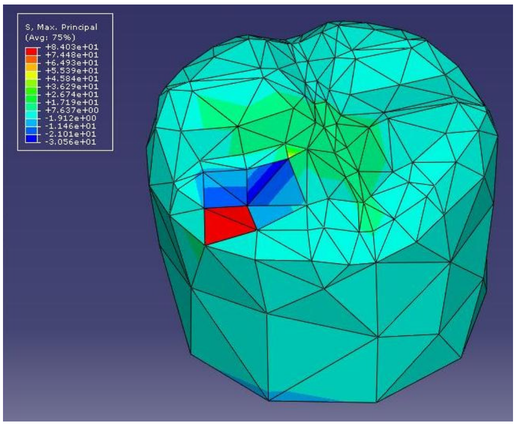

Figure 3: Principal Stress Distribution for an Eccentric Compression

The performed analytical study gives clues upon the stress distribution and values, deformations values in dental structures subjected to a known load and allows the choice of the optimum material and geometrical shape of the dental prosthetic works, according to real requirements.
Thus, the representation of the two types of strains clearly shows that the centric compression is uniformly distributed upon the tooth surface, leading to an almost uniform stress distribution, while the second type of strain, leads to a dangerous increase of the stress in the force action area, though the rest of the tooth remains in a comfortable strain zone.

For comparison we also performed models for other type of materials, usually used in dental prosthetics in order to estimate the opportunity of using composite materials, from mechanical point of view. The figure 4 presents the results obtained for an acrylate tooth subjected to an eccentric compression, which is obviously more likely to produce stress.

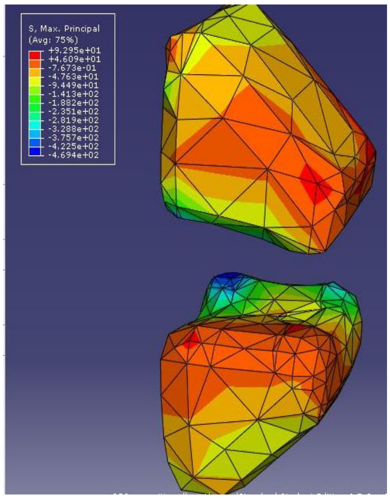

Figure 4: Principal Stress Distribution for an Acrylate Tooth Subjected to Eccentric Compression

The representations above confirm again that the stress is much higher in the area where the eccentric forces are acting and also the fact that the stress is considerably smaller and more uniform in the models designed of fibre reinforced composite materials.
We also were able to obtain the diagrams representing the force-displacement variation for both types of compression: centric (figure 5) and eccentric (figure 6).
Analyzing the diagrams we observe that the centric load leads to an almost uniform increase of the displacement with the force, while the eccentric one presents abrupt variations.

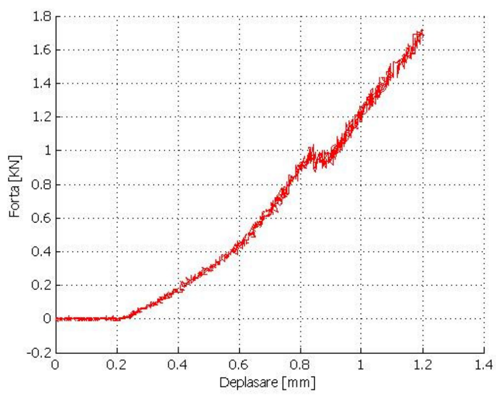

Figure 5: Force-Displacement Diagram for Centric Compression

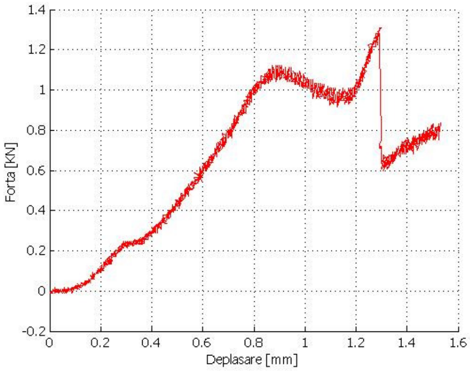

Figure 6: Force-Displacement Diagram for Eccentric Compression

EXPERIMENTAL RESULTS

The compression tests were performed using a Multipurpose Servohydraulic Universal Testing Machine, type LFV 50-HM. The maximum load force is ±50kN and the maximum stroke of the working head is up to 400mm.

The first tests were made for a centric compression as shown in figure 7.

Figure 7: Centric compression of the composite material tooth sample

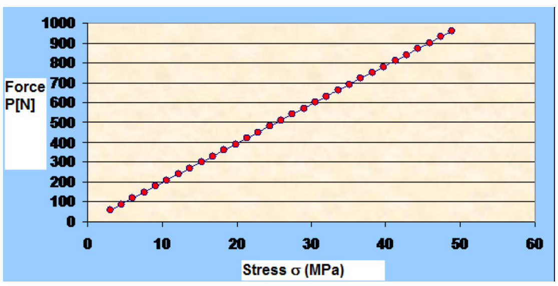

Figure 8: Value of stress depending on the applied centric compression force

Considering the compression force P, between 0 and 960N, the diagram in figure 8 was obtained for the corresponding stress during the experiment.

Further on the samples were subjected to an eccentric force placed as shown in figure 9.

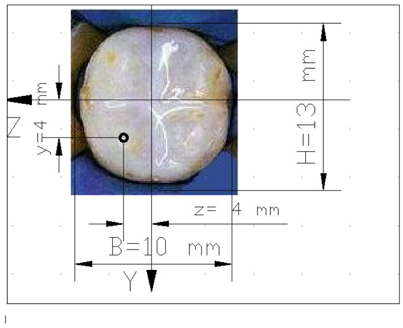

Figure 9: Location of the force point of application during the eccentric compression

Considering P between 300N and 990N to cover all the possibilities of bite forces, we are able to obtain the diagram of the stress depending on the force value, as shown in figure 10.

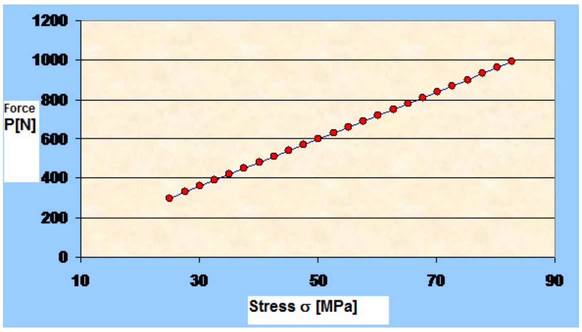

Figure 10: Value of stress depending on the applied eccentric compression force

Up to a certain value of the unit load the material behaves elastic, then it goes into plastic domain becoming unable to return to the initial size and shape. When the unit loading increases over the breaking strain value, the material deformation concentrates, a crack occurs leading to the sample break.

The experiments proved that the samples do not break up to 990N which is much higher than the bite force exerted by a human being.

CONCLUSIONS

The finite element analysis allows visualizing the areas where the principal stress appears in dental structures subjected to certain loads and creates the possibility of an accurate intervention in order to eliminate them.

Analyzing the principal stress, deformation and safety factors, we found that edges are most exposed so using corresponding methods to smooth surfaces becomes necessary.

The finite element analysis allows us to obtain enough data to determine the optimal shape and size of the dental prosthetic structures.
It will be also necessary to consider the fact that a small cross-section of the tooth (e.g. incisive or canine), leads to a bending tendency in horizontal plane so the rupture takes place horizontally.

REFERENCES

Cotoros, D. et al. 2009. "Aspects concerning impact tests on composites for rigid implants", *World Congress on Engineering, London England*, 1658-1661.

Stanciu, A.; D. Cotoros; M. Baritz; and M. Florescu. 2008. "Simulation of Mechanical Properties for Fibre Reinforced Composite Materials". *Theoretical and experimental aspects of continuum mechanics*, WSEAS Cambridge, 146-150.

Bratu, D. et al. 1994. "Materiale dentare-Materiale utilizate în cabinetul de stomatologie". Helicon Publishers. Bucharest, Romania.

Albrektsson, T. and Wennerberg, A. 2004. „Oral implant surfaces: part 1—review focusing on topographic and chemical properties of different surfaces and in vivo responses to them". Int. J. Prosthodont. 17, 536–543.

Regenio, M. et al. 2009. "Stress distribution of an internal connection implant prostheses set", Stomatologija, Baltic Dental and Maxillofacial Journal, 11, 55-59.

Baritz, M.; D. Cotoros; and L. Cristea. 2010. "Analysis of dental implants behavior in mobilizing prosthesis", The 12th Wseas International Conference on Mathematical and Computational Methods in Science and Engineering (MACMESE '10) Faro, Portugal, 141-145.

Cotoros, D. 2010. "Analysis of Skeletal Prosthesis Component Elements at Structural Level", Metalurgia International, No.7/2010, Bucharest, Romania (Jul).

AUTHOR BIOGRAPHIES

DIANA L. COTOROS was born in Brasov, Romania and went to the Transilvania University of Brasov, where she studied mechanical engineering and obtained her degree in 1986. She worked for five years for the Romanian Aircraft Company before moving in 1991 to Transilvania University of Brasov where she is now working with a research group in the field of simulation for biomechanical analysis and new implant materials identification. Her e-mail address is: `dcotoros@unitbv.ro` and her Web-page can be found at `http://www.unitbv.ro`.

ANCA E. STANCIU was born in Calarasi, Romania and went to the Transilvania University of Brasov, where she studied Technological Engineering and obtained her degree in 2005. She starts then as Ph.D. student in Transilvania University of Brasov and now is working as assistant professor. Her e-mail address is: `ancastanciu77@yahoo.com` and her Web-page can be found at `http://www.unitbv.ro`.

MIHAELA I. BARITZ was born in Bacau, Romania and went to Politehnica University of Bucharest, where she studied mechanical engineering and obtained her PhD degree in Fine Mechanics specialisation in 1997. She is now working in University Transilvania from Brasov in the field of optometry and biomechanical analysis for human behaviour. Her e-mail address is: `mbaritz@unitbv.ro` and her webpage can be found at `http://www.unitbv.ro`.