Use of the Finite Element Analysis Method in Pedodontics

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The purpose of this study was to determinate , using the Finite Element Analysis Method, the mechanical stress in a solid body , temporary molar restored with the self-curing GC material. The originality of our study consisted in using an accurate structural model and applying a concentrated force and a uniformly distributed pressure. Molar structure was meshed in a Solid Type 45 and the output data were obtained using the ANSYS software. The practical predictions can be made about the behavior of different restorations materials.

*Keywords: Finite element analysis method, temporary molars, GC materi*al

Engineering Science Based on Modeling and Simulation (M & S) is defined as the discipline that provides the scientific and mathematical basis for simulation of engineering systems, so a solid body can be mesh, that means split in finite elements , each element retained the physical-mechanical properties of the original material. It allows to establish the location,magnitude and direction of an applied force, as it may also assign stress points that can be theoretically measured [6,14] .

Experimental part

Material and method

An accurate structural model,was obtained by reproduction of the geometry of the temporary molar -periodontal-bone alveolar space ensemble, using the anatomical configuration of lower M2T; an isometric, orthoradial and retroalveolar X-ray of a lower M2T was photographed and the results were compared with the average dimensions and measurements of a real tooth [2]. Thus, several points were defined in the XOY plan, on different coordinates, causing the areas of different tooth structure. The working variant was a lower M2T with a class I preparation and with self-cured GC restoration.

To determinate the mechanical stress ,a concentrated force and a uniformly distributed pressure was applied, because under the action of mastication force the tooth was subjected to: compression and tensile stress, shear stress, and deformations, etc .The physical-mechanical properties of the temporary teeth structures (elasticity modules, Poisson coefficient, density) and of the GC self-curing material used (not disclosed by the manufacturer) were taken from the studied literature (table1) [9]. The tooth behaves as a solid body, analyzing the values of the elasticity modules of the enamel and dentin, was found that while the enamel is a rigid structure, dentin is an elastic structure, so that the tensile strength of the dentin is 3-4 times greater than the enamel. The stress consists of determining the following types of mechanical stresses: S_1 (stress that calculates most the tensile stress);S_2 (stress that calculates the tensile stress and compresion stress in equilibrium);S_3 (stress that calculates most the compresion stress) and the Von Mises stress() $\sigma_{MISES} = \sqrt{\sigma_X^2 + \sigma_Y^2 - \sigma_X \cdot \sigma_Y + \tau_{XY}^2}$ [10-12].The output data are obtained using the ANSYS software.

Results and dicussions

The most important step was to mesh teeth structure in Solid Type 45, resulting a mesh structure in 23422 nodes. After that, there were applied two loading case on the surface of the tooth (different values and distributions). In the figure 1 there are presented the studied meshed tooth structure

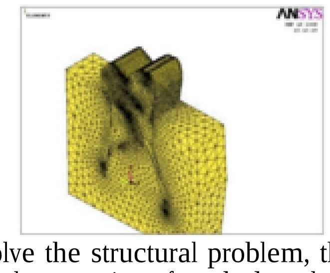

Fig. 1 The meshed structure

To resolve the structural problem, the corresponding mechanical properties of each dental structure and GC restoration was introduced (table 1).

Tabel 1

MECHANICAL PROPERTIES OF DENTAL STUCURE AND GC MATERIALS [9]

Material	*Young elsatisticity modules*	*Poisson contraction coeficient υ*
Dentin	1,89 x 10^9 N/m^2	0,31
Cement	2,00 x 10^9 N/m^2	0,16
Pulp	0,10 x 10^9 N/m^2	0,45
Enamel	8,40 x 10^9 N/m^2	0,33
GC self-cured	0,60 x 10^9 N/m^2	-

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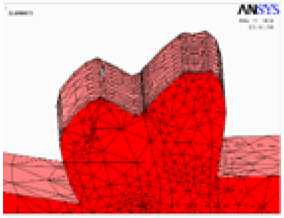

Fig. 2. Force application of tooth structure

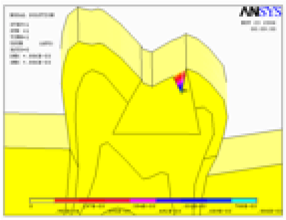

Fig.3. The deformation sum of tooth structure

The working variant was a lower M2T with a class I preparation with selfcured GC restoration, because it is the most commonly restoration material used in the pedodontic practice. The first loading case is concentrated force of 30 N, value was consistent with data from the literature [11]. The force orientation on the tooth surface and its geometry are shown in figure 2. As a result of this mastication force, in the figure 3 the sum of the deformations were presented.

As a result of this concentrated force, the structure of the GC restoration was distorted and the deformations had values of the order of tenths of a millimeter. Values were considered high for such a structure, corresponding to the axis on which the force is applied (OY, occlusal). In the figure 4, the deformations are presented on this axis. In this case, their numerical was $0.8 \cdot 10^{-3}$ m.

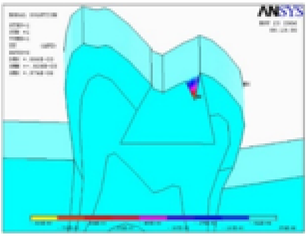

Fig.4 The deformation on the OY axis

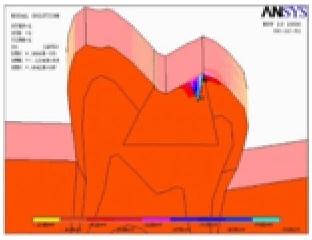

Fig. 5 The S1 stress ($0.6 \cdot 10^9 N/mm^2$)

In the figure 5, the S_1 stress are calculated and the stress value, important as a numerical value, appears in the GC restorations structure, which exceeds the value of the modulus of elasticity for the GC. These values $\sigma = 0.6 \times 10^9$ N/m^2 lead to the plastic modification of the geometric shape of the restoration or even the structure destruction.

In the figure 6, the S_2 stress indicates the same high values in the material structure ($\sigma = 0.35 \times 10^9$ N/m^2), almost the same values in compression and tensile. In the figure 7, the S_3 stress indicated high values in the material, $\sigma = 0.21 \times 10^9$ N/m^2 but also an important distribution of

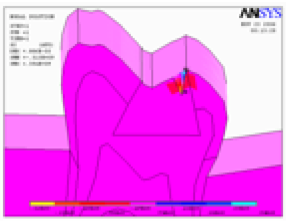

Fig. 6 The S_2 stress ($\sigma = 0.35 \times 10^9$ N/m^2)

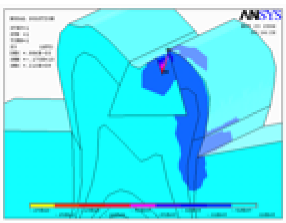

Fig.7 The S_3 stress ($\sigma = 0.21 \times 10^9$ N/m^2)

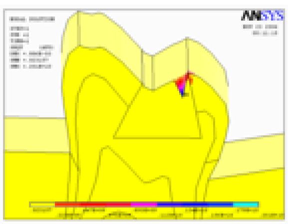

Fig.8 The values of Von Mises stress

stress due to force F in the tooth structure (enamel and dentin structures).

From the point of view of the Von Misses stress, the calculations indicates the presence of dangerous values that could destroy the GC restoration. The VM stress are approaching as a value of dentin elasticity module, may in certain conditions lead to destroying it. Following this analysis the self-cured GC restoration was much less resistant than that of other materials (fig . 8).

One of the advantages of using FEM analysis was choosing the optimal conditions, without the danger of destroying the structures. In the next stage the force had been reduced to a new value (F = 5 N), the movements of the structure are very small, by the order of the micron). This very small value was chosen, precisely to present the difference between the two cases studied. These deformations are however produced by a state of tension within the limit $\sigma = 0.3 \times 10^8$ N/m^2, lower than the elasticity module of the self-cured GC , but of comparable values. In these circumstances, exceeding the value of F = 5 N had become dangerous in the new conditions as well. In figure 9, the S_1 stress map is presented according to this. The S_2 stress map is presented in the figure 10 with higher value $\sigma = 0.19 \times 10^8$ N/m^2, less than Young Modulus, but with important values.

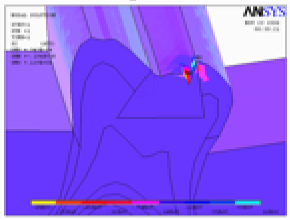

Fig. 9 S_1 Stress map for the $F_1 = 5$ N

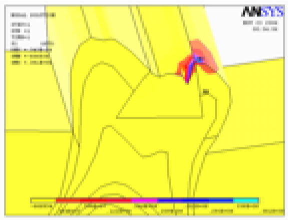

Fig. 10 The State of second order (S2)

In the case of the Von Misses stress, their values were somewhat higher and closer to the GC elasticity module, but with some reservations until this value was reached.

Use of the FEM analysis in the field of dental medicine, is very useful for helping to analyze the behavior of a dental structure under the action of masticatory forces.The need for a large number of natural teeth for experiments is eliminated, so patients are not at all affected .The advantage of the method is that it can be studied any geometric shape of the tooth structure under any working conditions, but the major disadvantage is that it analyze a static situation. The force-driven request causes a state of effort, compression, or tensile. The area of force application is observed in a very high compression unit efforts (2756-2809 daN/cm^2) on the enamel and on one side of this area, large stretching efforts (400-800 daN/cm^2).Normal, the compression efforts dominated the enamel, but if the distance from the force's application area zone increases, the efforts decrease. Thus, along the vestibular face is evident this decrease, registering a higher value (1031 daN/cm^2) only at the level of the package. In the oral cusp, which the force does not exert directly, the efforts are very small. Generally, it is observed the divergent disposition of the efforts from the place of application of force to the two sides of the bucal cusp, and then become parallel to the junction of the enamel-cement. The absence of this divergent provision in oral cusp, not subject to direct force action, stresses the role of cusps lopes in the takeover and transmission of forces according to their point of application. In dentine, compression efforts are close to value and do not generally exceed 300 daN/cm^2, except the area under the enamel directly requested (values above 300 daN/cm^2) and in the neighbourhood of the long axis of the pulp chamber (values higher than 400 daN/cm^2, even 900 daN/cm^{2}at the oral pulp horn level).In dentin there are more extensive areas required by tensile stress.The compression efforts are produced in the vertical direction and the tensile on the transverse direction.In cement, as in root dentine, the main efforts are oriented roughly parallel to the outer surface of the root and generally have small values, with the exception of the apical area where they reach high values (1900 daN/cm^2). Also, the main efforts are something greater on the side of force enforcement in relation to the opposite side.In the M2T with occlusal self-cured GC restoration, a concentrated force worth 30 N, determined the fracture of the filling, but at a lower values of the force the restoration lasts. If a uniformly distributed force was applied, the GC restoration deforms significantly (tenths of millimeters) at much lower values of the applied force, while comparing with other fillings materials.

Conclusions

The applied concentrated forces determined compression and tensile effects in the dental structures;maximum compression and maximum tensile stress appear in dentin and in areas between dentin and enamel and between dentin and pulp organ;

The enamel being a more rigid structure deformed less under the action of concentrated force by overstress the underlying layers.; dentine acquired a more pronounced axial deformation, thus recording a higher dilatation;

Temporary molar behave under the action of external applications as a solid, elastic body subject , but unlike permanent teeth, temporary teeth present a tensile strength of 2.5 -3.5 times lower;.

On compression stress, the tooth enamel had different mechanical properties depen-ding on the coronary area, so there was an increased tensile strength of the enamel in the cusp areas compared to the enamel on the vertical surfaces of the teeth;on tensile stress, the enamel presents high values of mechanical stress and low values of the tensile stress regardless of the dental group or the topographic area , resulting that the enamel is presented as a rigid and little elastic structure;

On compression stress, dentine had relatively constant values of the tensile strength regardless of the dental group or the topographic area of the tooth crown, with the indication that root dentine has a elasticity module of 1.35 times lower and a tensile strength less than crown dentine;dentine behaved as an elastic structure compared to the enamel, constituting a real elastic *cushion* for enamel with an important role in the depreciation of shocks;

About mechanical behaviour of the self-cured GC restored molar , it was noticed that he resisted at lower forces than others restorations.

In conclusion the practical importance of this analysis consisted in predicting the mechanical behavior of different filling materials.

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