INFLUENCE OF DENTAL MATERIALS ON THE TOOTH STRUCTURE: FINITE ELEMENTS METHOD STUDY

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ABSTRACT

The purpose of this study is to evaluate the behavior of dental materials used in tooth restoration and the effects of these materials on intact and restaurated tooth structure. Our study uses finite elements method (FEM) owing to its multiple advantages.

Keywords: dental materials, lesion, restorations, tooth structure, finite elements

1. Introduction

The destructive processes that originate on the external surface and affect the teeth causing irreversible loss to the tooth structure are described, such as erosion, abrasion, attrition and abfraction.

One current hypothesis is that the tensile or compressive strains gradually produce micro fractures.

The tooth has not a rigid structure; hence it can suffer strains when various forces/loads are applied. Intraoral loads vary from 10N to 430N, the normal.

Cervical areas are morphologically and histological different from the crown and the root portions of the tooth. Mechanical interlocking between enamel and dentin in the cervical area is weaker than that in the other regions of dentin-enamel junction. Furthermore, this area has an aprismal enamel and contains less mineral.

These structural features may adversely affect the performance of the restorative materials used in the cervical area.

FEM is one of the more recently used techniques for stress analysis. FEM divides the problem domain into a collection of smaller elements. An overall approximated solution to the original problem is determined.

The purpose of this study is to evaluate the behavior of dental materials used in cervical lesion restorations and their effect on tooth structure.

2. Materials and Method

A two-dimensional finite elements analysis model was generated for analysis, using an intact normal human mandibular canine.

A plan model reproducing a vestibular and lingual section of the lower canine was created. The finite elements are type 2D. A denser mesh with a large number of EF was built in the area of interest in order to obtain the best replica of the tooth and the most faithful analyses of the situation.

The quality of the analysis results depends on the accuracy of the model.

Fig.1. 2-D model of the lower canine used in study

To simulate material continuity, all the parts of the dental structure are considered connected and forming whole body.

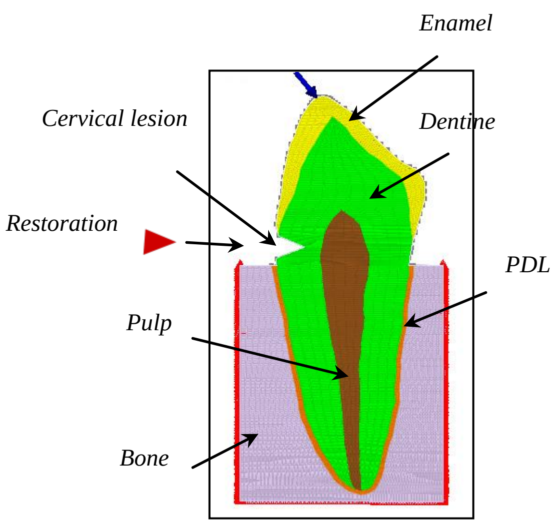

Fig. 1: 2-D model of the lower canine used in study

Our study used four restorative materials: GIC, Dyract AP, Vitremer, Fuji IX.

Table 1. Mechanical properties of the materials

Materials	Young's modulus E [N/mm ^{2} = MPa]	Poisson's ratio μ
Dentine	$1{,}67\cdot10^{4}$	0,3
Enamel	$6{,}9.10^{4}$	0,3
GIC	$1{,}08.10^{4}$	0,3
Dyract AP	$1{,}07.10^{4}$	0,28
Vitremer	$0{,}98.10^{4}$	0,3
Fuji IX	$1{,}72.10^{4}$	0,3

All materials were considered elastic (right proportion between stresses and specific strain and Hooke law valability) and isotropic (with identical elastic characteristics on all directions) even if the components of the structures are not fully homogeneous.

In order to obtain a situation as close to reality as possible, the model loading was achieved with a charge distributed on five different nodes. Nodal charges were of 40 degrees to vertical, applied on the vestibular side at h = 8,993 mm to colet, of increasing magnitudes: F = 20 N; F = 40 N; F = 60 N; F = 80 N; F = 100 N; F = 120 N; F = 140 N; F = 160 N.

The model was generated bearing in mind the ideal medical situation that is to present adhesion between tooth and restoration.

3. Results

Based on the simulations carried on both for restorative materials and for the periodontal structure materials, the characteristic curves of the materials were drawn – the proportion between stress [MPa] and strain [mm/mm].

A comparation between elastic characteristics of the materials in study vs. dentine was carried out (Fig.2., Fig.3., Fig.4., Fig.5., Fig.6.).

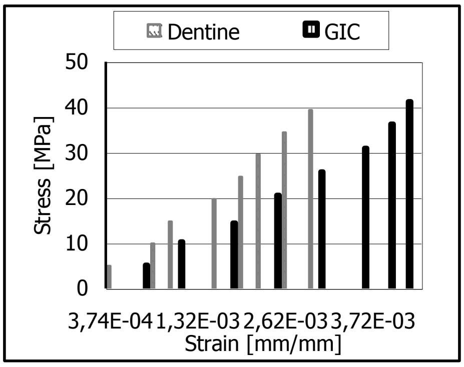

Fig.2. Comparison stress– strain Dentine-GIC

After interpreting the results of the simulations, a proportionality between stress and strain is evident for all restorative materials and dentine, thus validating Hooke law $\sigma = E\,\varepsilon$.

The elastic characteristics of Fuji IX ($E=1{,}72x10^{4}$ MPa) are the closest to those dentine ($E=1{,}72x10^{4}$ MPa) exhibiting the greatest compatibility.

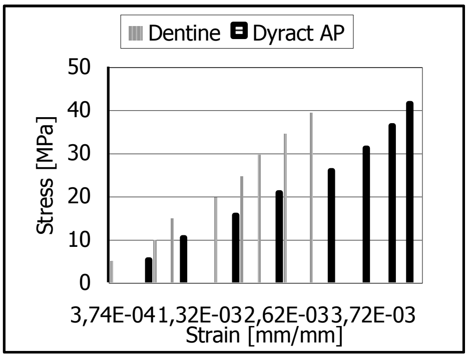

Fig.3. Comparison stress – strain

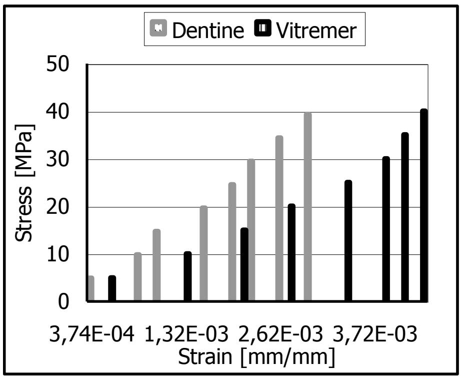

Fig. 4. Comparison stress – strain Dentine-Vitremer

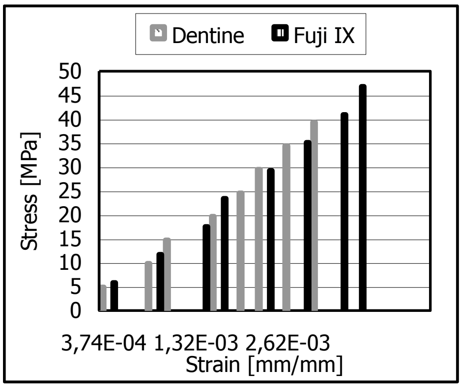

Fig.5. Comparison stress– strain Dentine-Fuji IX Dentine-Dyract AP

The almost identical elastic characteristics of Fuji IX and dentine correspond to higher rigidity and lesser elasticity materials as compared to the other materials used in the study (GIC, Dyract AP, Vitremer).

The elastic characteristics of GIC, Dyract AP and Vitremer are fairly close, exhibiting a higher elasticity than that of Fuji IX.

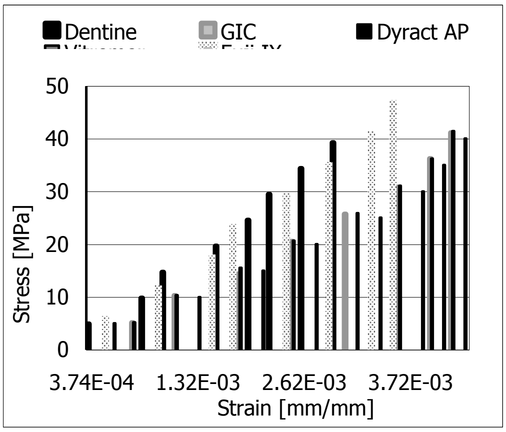

Fig.6. Comparison for different materials: Stress [MPa] – Strain [mm/mm]

Our study deemed as significant analyzing the variation of equivalent stress values (Von Mises).

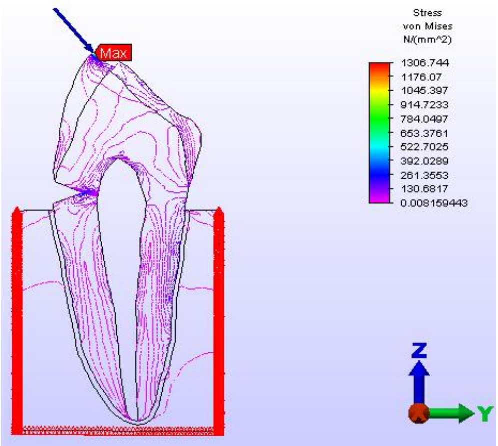

Fig.7. Von Mises stresses for F= 140 N Tooth with cervical lesion

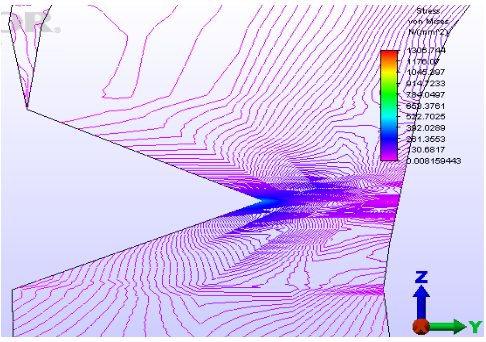

Fig.8. Detail – Stress Von Mises

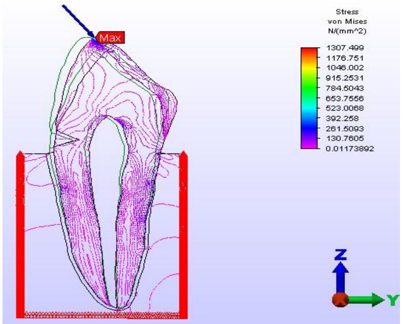

Fig.9. Von Mises stresses for F= 140 N Tooth with restoration – Fuji IX

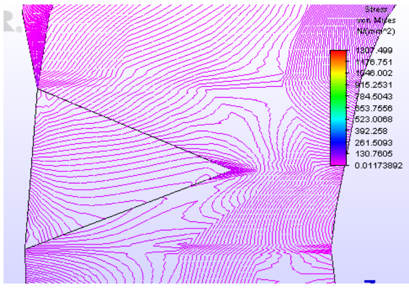

Fig. 10. Detail – Stress Von Mises

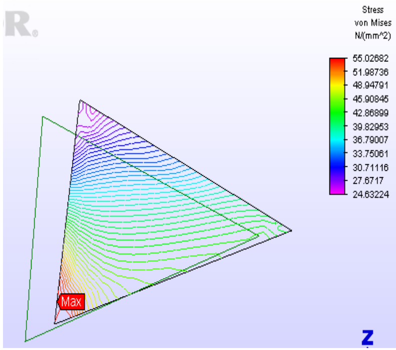

Fig. 11. Restoration Stress Von Mises for F=140 N

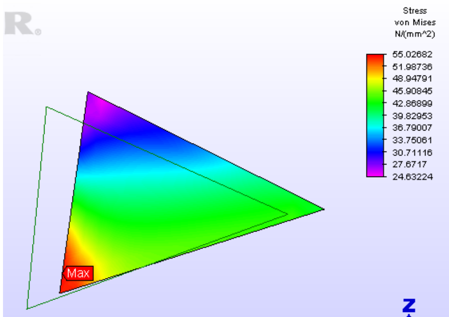

Fig. 12. Restoration – Stress Von Mises for F=140 N

The Von Mises stresses in the unrestored tooth and Fuji IX restoration is compared (Fig.7., Fig.8., Fig.9., Fig.10., Fig.12., Fig.13.).

Since lesions are mostly found in dentine and enamel area, our study assesses the effect of restorations with different dental materials through Von Mises stress variation in dentine and enamel.

4. Conclusions

After interpreting the results obtained following the simulations, the conclusions are:

- For all reconstructions using the four materials, the Von Mises equivalent stress observed in all periodontal structure elements showed lesser values as compared to the lesion tooth;
- After restoration the area of stress concentration in the bottom of the cavity disappears (Fig.10., Fig.11., Fig.12.);
- The behavior of the restored tooth using the four materials is similar to that of the healthy tooth;
- Tests showed that loads over F=80N damage the tooth structure (since maximum strain for the dentine is: $\sigma_{a\ dentine}$ = 105,5 MPa [2008, Shubhashini Narayanaswamy];

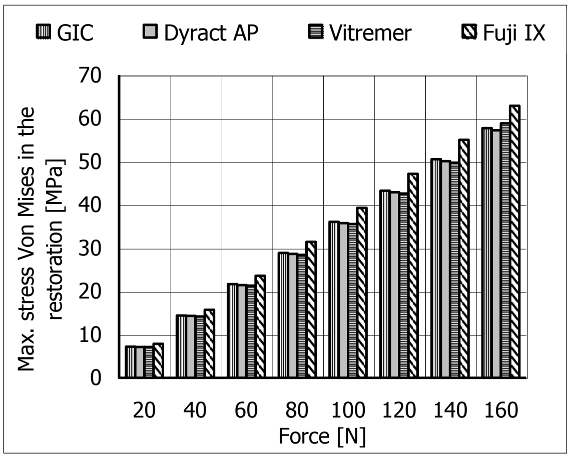

Fig.13. Maximum stress Von Mises in restoration

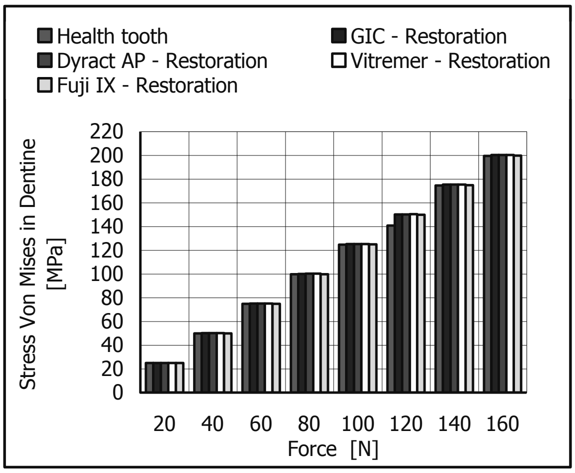

Fig.14. Maxim stress Von Mises in dentine

- Consequently, loads of F=80N and less correspond to the maximum strain of the dental materials used in our study [2005, RG Balaji];
- GIC, Dyract AP and Vitremer exhibited closed values of stress while Fuji IX exhibited a highest values of stress; on the other hand a stress relaxation in dentine was noted after restoration with Fuji IX;
- Fuji IX was the only restoration material of the four that led to a stress distribution similar to that in the healthy tooth;
- The elastic characteristics of Fuji IX recommend it for restorations in areas of thicker enamel and dentine layers;

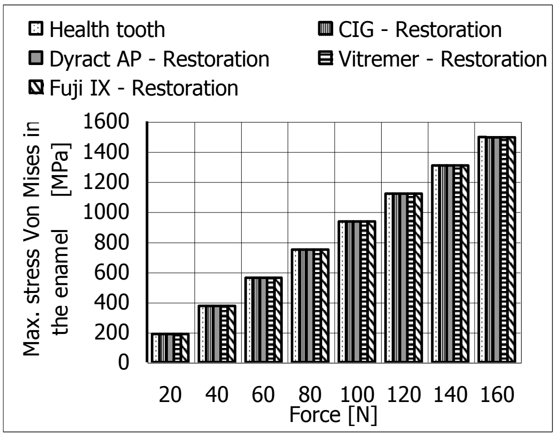

Fig.15.Maxim stress Von Mises in enamel

- The elastic characteristics of GIC, Dyract AP and Vitremer recommend them for restorations in areas of thinner dentine layers;
- It is recommended that class V cavities be rounded off before restoration since a wedge-shaped cavity constitutes the highest stress concentrator.

The study showed beyond no doubt that the restoration materials should be used according to the closeness between their elastic characteristics and those of the area they are used for (Young's modulus and Poisson ratio).

5. References

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