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FEM STUDY: CERVICAL LESIONS MECHANISM FORMATION

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ABSTRACT

The causes of dental abfraction used to be a controversial subject. Although mechanical theory gained popularity, the mechanism of formation of cervical lesions is not fully explained. This approach points to the conclusion that the cervical area of the tooth, where this type of lesion usually occurs, concentrates the stress resulted from the action of the forces applied on various areas of the crown. Moreover, any lesion in the cervical area facilitates the possibility of its advance into the tooth, ultimately fracturing it. Our paper presents the mechanical analysis using the finite elements method (FEM) of a tooth under two different loads.

Keywords: finite element analysis, abfraction, non-carious cervical tooth loss, stress, displacement

1. Introduction

Non-carious cervical lesions (NCCLs) represent a challenging problem of oral health.

For the past 20 years it has been considered that the etiology of these angular lesions consists of dental flexure caused by tensile stress.

Occlusal stress factors have gained increasing attention as causes of non carious cervical lesions. In 1991 Grippo introduced the term abfraction to designate stress induced lesions that result from hyperfunction and parafunction.

Abfractive lesions are mostly wedge shaped and develop over time as hard tissue defects in the cervical region of teeth commonly in the vestibular or lingual aspects. They are more commonly seen in the mandibular teeth, which may be due to their lingual orientation and their anatomically smaller cervical cross section.

The exact cause of abfraction has not been conclusively proved. Studies by Celik (1992) and Spears (1993) have shown that the enamel and dentin together with the entire masticator apparatus are superbly designed to dissipate compressive forces during function. But when a tensile stress is generated as a result of lateral stresses acting on teeth, they do not dissipate but instead tend to concentrate near the cervical region. This tensile stress concentrating near the cervical region disrupts the chemical bonds of the crystalline structure of enamel and dentin. Small molecules can enter the micro cracks and prevent reformation of the chemical bonds. The resultant damaged tooth structure is subsequently lost.

The values of intraoral loads (forces) may be on 10N to 430N, but the normal value is 70N.

Forces applied on the cervical area leads to cervical lesions usually (Fig.1). As a type V cavity.

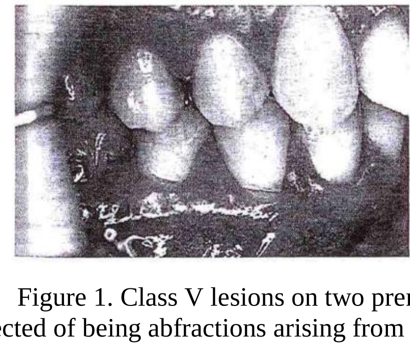

Figure 1. Class V lesions on two premolars suspected of being abfractions arising from tooth [5]

Tooth structure is heterogeneous and asymmetric and its properties change in time. According to the theory of tooth flexure, parafunction forces in areas where interferences occur, principally lateral areas, can expose one or more teeth to strong tensional, compressive or shearing pressure. The forces causes micro cracks in the dental structure. It is believed that, with time, the micro cracks spread of the teeth under pressure until the enamel and the dentin are broken [5].

The aim of this study was a FEM study of the mechanism of cervical lesion formation in teeth

The tensile stress leads to lateral flexure while vertical stress leads to axial compression of the tooth (Fig.2).

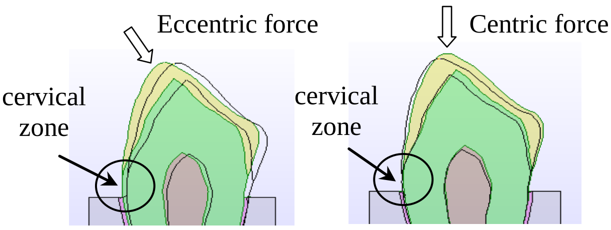

Figure 2 Schematic diagram of tooth flexure creating cervical stresses

2. Materials and Methods

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

The outline of the tooth including: tooth – PDL - alveolar bone – pulp, was represented on a 2D model (Fig.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).

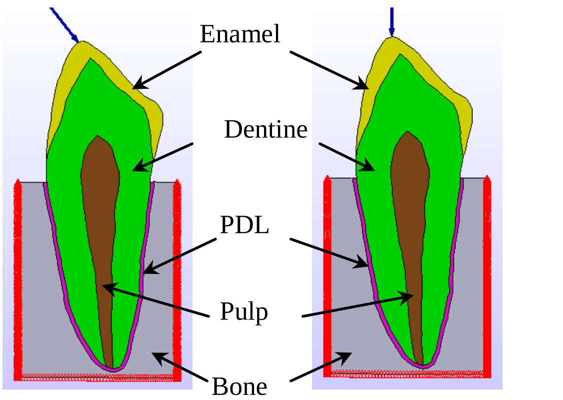

Figure 3. 2-D model of the lower canine used in study

Modulus of elasticity *E* (Young modulus) and Poisson's ratio μ, values for the materials used in the model were derived from standard texts [3].

Two situations of tooth loading were considered:

a. Oblique nodal force at 40 degrees to vertical applied on the vestibular aspect at height of 8.993mm from cervical area and of increasing magnitudes: 40N, 80N, 120N, 160N and 200N (Fig.3.a.);

b. Vertical nodal force of increasing magnitudes: 40N, 80N, 120N, 160N and 200 N applied on the tip of the tooth (Fig.3.b).

The forces applied were of the same values, both for the vertical and tensile stress, in order to obtain the most accurate results by means of comparison of the two situations.

A vertical plane model of a lower canine corresponding to the lingual and vestibular aspect was created. The finite elements are of a two-dimensional type (2D) – quadrilater. A denser mesh with a larger number of EF was build in order to obtain the best replica of the tooth and the most faithful analyses of the situation in the areas of interest.

The model of a healthy tooth is composed by:

- Nodes = 10001
- EF no = 9691

of which:

- tooth: EF no = 1976
- enamel: EF no = 984
- PDL: EF no = 957
- bone: EF no = 5010
- pulp: EF no = 764

3. Results

As a result of our study, which used loadings of increasing magnitudes in both vertical and tensile positions, it was noted that the cervical area is the one reserving most of the stress thus becoming prone to mechanical damage expressed in cervical lesions.

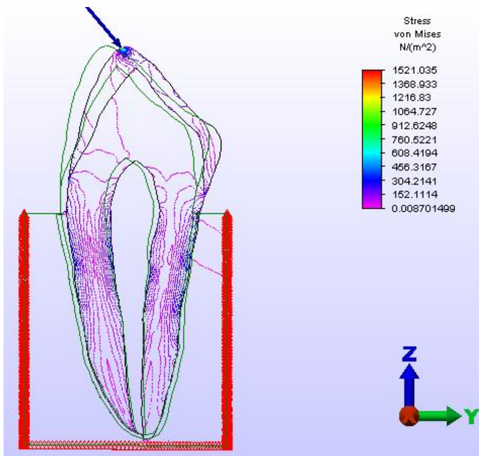

Figure 4. Von Mises equivalent stress distribution. Curves of equal value corresponding to a eccentric force: F=160N

In the study of the cervical area sensitive to mechanical lesions the following significant values were considered:

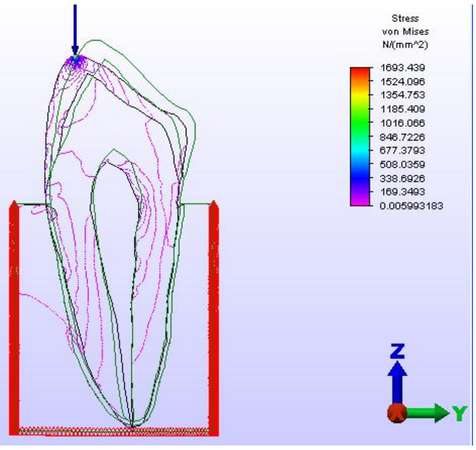

Figure 5. Von Mises equivalent stress distribution Curves of equal value corresponding to a centric force: F=160N

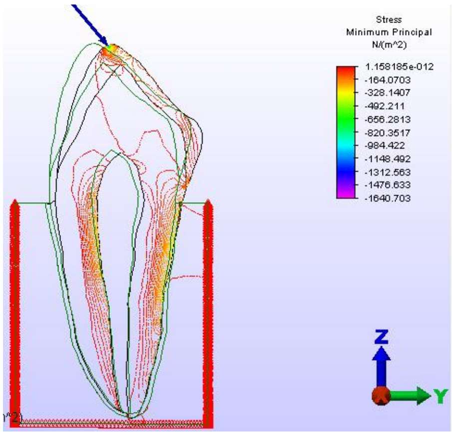

Figure 6. Minimum principal stress distribution – curves equal displacement. Deformed position of the structure of a eccentric force: F=160N

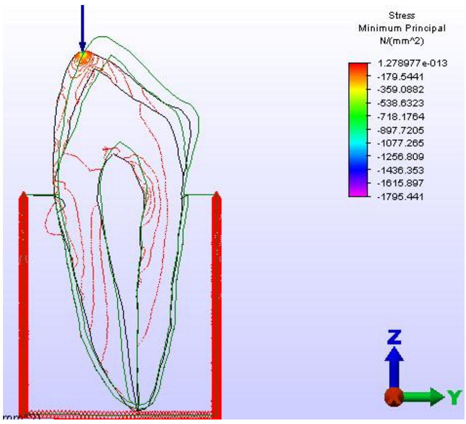

Figure 7. Minimum principal stress distribution – curves equal displacement. Deformed position of the structure of a centric force F=160N

- Equivalent stress Von Mises σ_{ech};
- Stress following tooth direction Z-Z;
- Minimum principal stress (compression effect) σ_2;
- Resultant displacement.

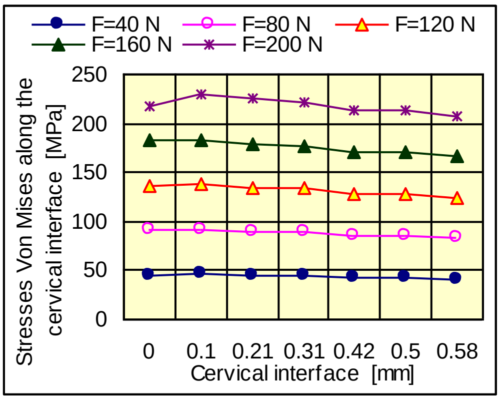

Figure 8. Equivalent stress Von Mises in the cervical area at various values of eccentric force at 40º

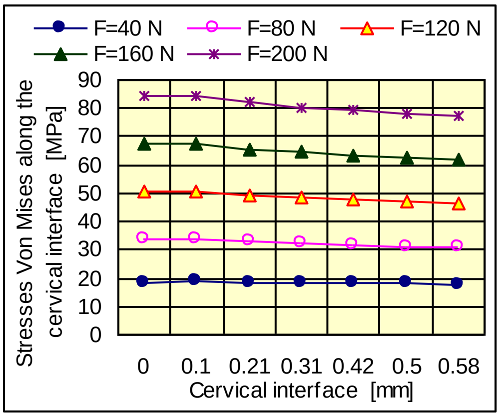

Figure 9. Equivalent stress Von Mises stress in the cervical area at various values of centric force

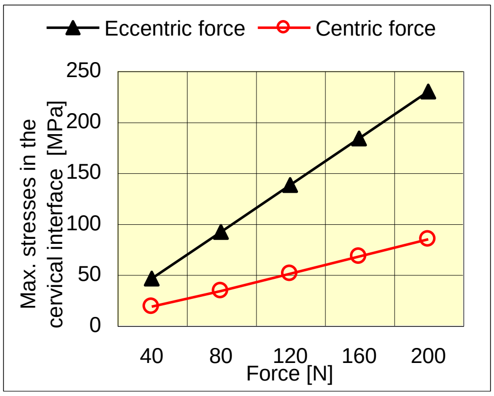

Figure 10. Comparison: eccentric force – centric force The node with maximum stress Von Mises values (0,1 mm from colet)

Corresponding to the values obtained by simulation in Fig.4, Fig.5, Fig.6, Fig.7 and Fig.12, stress values variation versus cervical area displacement graphs have been built; maximum values for both displacement and stress appeared in the cervical area Fig.8, Fig.9, Fig.10 and Fig.11.

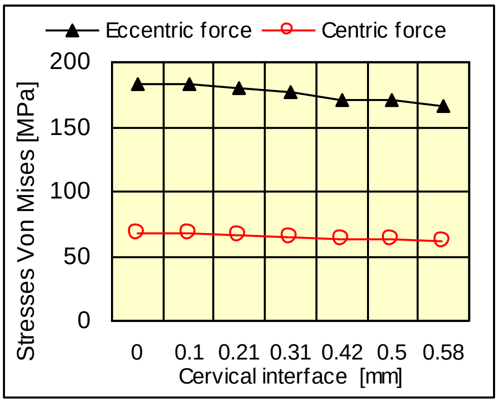

Figure 11. Von Mises equivalent stress variation in the cervical area for different position of a force: F=160N

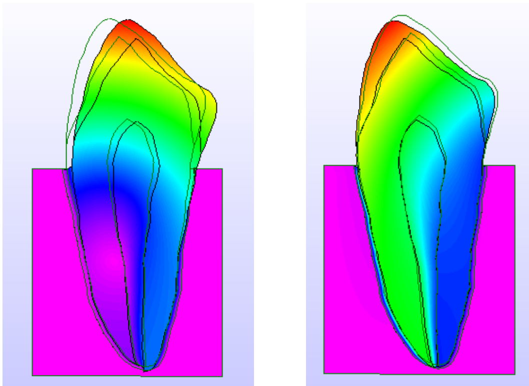

Figure 12. Displacement distribution – areas of equal displacement. Deformed position of the structure for different position of forces (eccentric-centric)

4. Conclusions

Based on the results obtained, the following conclusions appeared:

- maximum load, irrespective of stress direction, involves the cervical area (Fig.2);
- maximum stress values are obtained onto the cervical area, at 0,1mm from colet (Fig.8. and Fig.9);
- cervical area stress values increase with occlusal stress (Fig.8. and Fig.9);
- Von Mises equivalent stress values, for the same value of the stress, are higher in the tilted position of the stress (Fig.10. and Fig.11).

From a mechanical point of view, the maximum stress is localized in the cervical area, regardless of the occlusal contacts or force position. In this area flexion of the teeth and stress concentration occur leading to a possible fissure at this level

In conclusion, this study has found that de displacement of dental structure undermining in the cervical lesion may result in bulk enamel loss. This may cause crack initiation in the dental structure, eventually leading to bulk loss. Occlusal stress factors have gained increasing attention as causes cervical lesions.

5. References

[1] Beata Dejak, Andrzej Mlotkowski, Maciej Romanowicz, The Journal of Prosthetic Dentistry, Volume 94, Number 6, deccember, 2005;

[2] Boitor, C, Frățilă, A, Ionaș, M, Pascu, A, Oleksik, V, Pârvu, B, Analiza prin metoda elementului finit a leziunilor de abfracție dentară, Revista Română de Stomatologie, Vol LV, Nr. 4, 2009;

[3] Gurbuz, T, Sengul, F, Altun, C, "Finite Element Stress Analysis of Short-post Core and Over Restorations Prepared with Different Restorative Materials", Dental Materials Journal, Vol. 27(4), (2008), 499-507;

[4] J.S. Rees, M. Hammadeh, Undermining of enamel as a mechanism of abfraction lesion formation: a finite element study, European Journal of Oral Sciences, No. 112: 347-352, 2004;

[5] Roberson TM, Heymann HO, Swift EJ, Art and Science of Operative Dentistry, 2006.