UNIVERSITATEA Petru Maior TÂRGU-MUREŞ

Scientific Bulletin of the „Petru Maior" University of Tîrgu Mureş
Vol. 7 (XXIV), no. 2, 2010, ISSN 1841-9267

EFFECT OF CERVICAL LESIONS ON THE TOOTH: FEM STUDY

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ABSTRACT
The approach used until recently concerning the phenomena of dental abfraction points to the conclusion that the cervical area of the tooth, were this type of lesion usually occur, concentrates the stress resulted from the action of the forces applied on various areas on the crown. Moreover, any lesion in the cervical area facilitates the possibility of its advance into the tooth, ultimately fracturing it. Our paper presents a FEM (finite element method) study on the results of a mechanical analysis of the phenomena involving the tooth damaged by cervical lesions.

Keywords: finite element analysis, cervical lesion abfraction, stress, displacement

1. Introduction

Human tooth represents a wonder of nature. However, there is a major problem about it, namely, its limited capacity of regeneration, leading to the necessity of replacing the lost structure resulting from cervical lesions by means of restorative materials.

Forces applied on the cervical area leads to cervical lesions usually as a type V cavity (Fig.1.). Any tooth already exhibiting a lesion on its colet, exposed to forces of various magnitudes and angles, will suffer an increase of the stress on the much damaged area. The lesion will become a stress concentrator leading to cracks and their propagation into the tooth ultimately leading to fracture.

Fig.1. Class V lesions on two premolars suspected of being abfractions arising from tooth

Our paper presents a FEM study on a tooth exhibiting a cervical lesion observing the phenomena taking place into the tooth at lesion level under forces of various magnitudes and angles.

2. Materials and Methods

A two-dimensional mathematical finite elements analysis model was generated for analysis, using intact normal extracted human mandibular canine. The quality of the analysis results depends on the accuracy of the model.

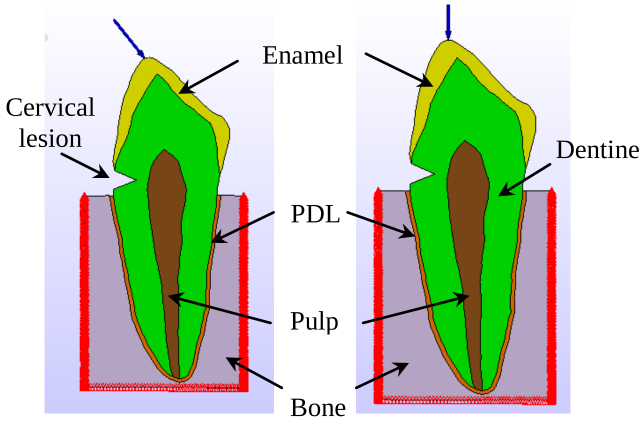

Figure 2. 2-D model of the lower canine with cervical lesion used in study
a. eccentric force b. centric force

A plan model reproducing a vestibular and lingual section of the lower canine was created. The finite elements are type of 2D. To simulate material continuity, all the parts of the dental structure are considered connected and forming whole body (Fig.2).

All materials were considered elastic (right proportion between stresses and specific strain and Hooke law availability) and isotropic (with identical elastic characteristics on all directions).

Modulus of elasticity (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 8.993 mm from cervical area of increasing magnitudes: 40N, 80N, 120N, 160N and 200N (Fig.2.a.);

b. Vertical nodal force of increasing magnitudes: 40N, 80N, 120N, 160N and 200N applied on the tip of the tooth (Fig.2.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 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 the damaged tooth (Fig.2) / class V cavity is composed of:

- Nodes = 10324
- EF no = 9991

of which:

- Tooth: EF no = 2160
- Enamel: EF no = 1008
- PDL: EF no = 957
- Bone: EF no = 5010
- Pulp: EF no = 856

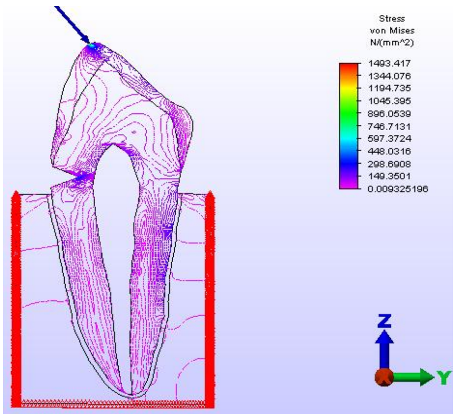

Figure 3. Equivalent stress Von Mises distribution Curves of equal values corresponding to a eccentric force of F=160N

3. Results

The results obtained following simulation on a tooth with a cervical lesion both for the tensile loading and the axial direction of the force, have been compared to the results obtained following simulation on the intact tooth in the same condition.

The significant results bearing relevance to the phenomena are following:

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

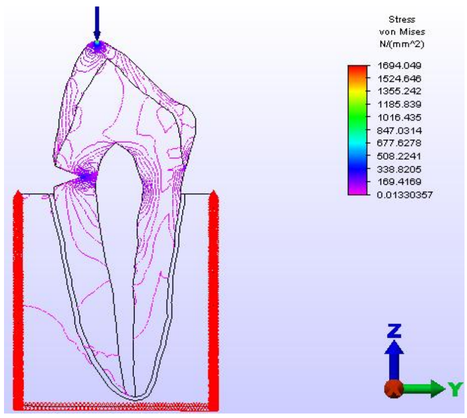

Figure 4. Equivalent stress Von Mises distribution. Curves of equal values corresponding to a centric force of F=160N

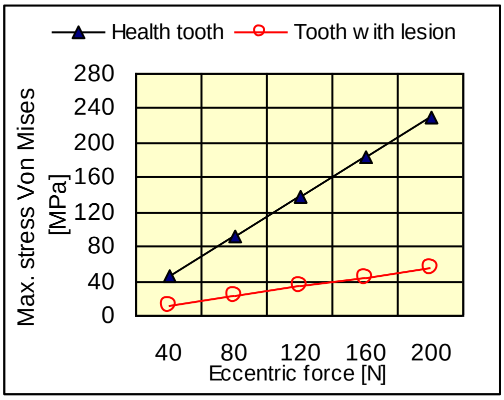

Figure 5. Comparison: intact tooth – tooth with cervical lesion for eccentric force
The node with maximum stress Von Mises values (0,1 mm from colet)

Stress values variation together with cervical area displacement graphs have been built corresponding to the values obtained following simulation (Fig.3, Fig.4, Fig.7, Fig.8, Fig.12. and Fig.13); maximum values for both displacement and stress appeared in the cervical area (Fig.5, Fig.6, Fig. 14,. and Fig. 15).

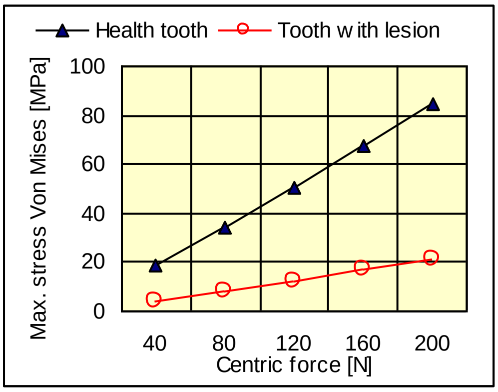

Figure 6. Comparison: intact tooth – tooth with cervical lesion for centric force
The node with maximum stress Von Mises values (0,1 mm from colet)

Maximum tensile stress

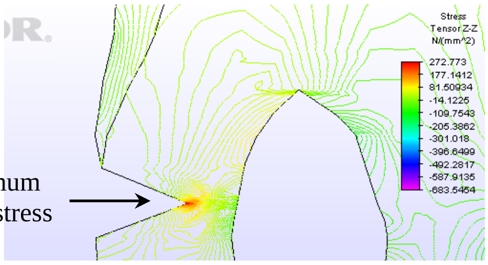

Figure 7. Stress distribution following vertical axes of the tooth Z-Z in the bottom of the lesion for the eccentric force (positive values in the lesion)

Maximum compressive stress

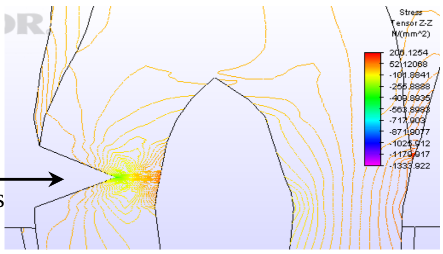

Figure 8. Stress distribution following vertical axes of the tooth Z-Z in the bottom of the lesion for the centric force (negative values in the lesion)

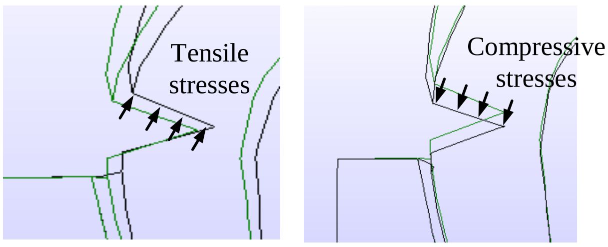

Figure 9. Deformed position of the lesion
a.eccentric force b. centric force

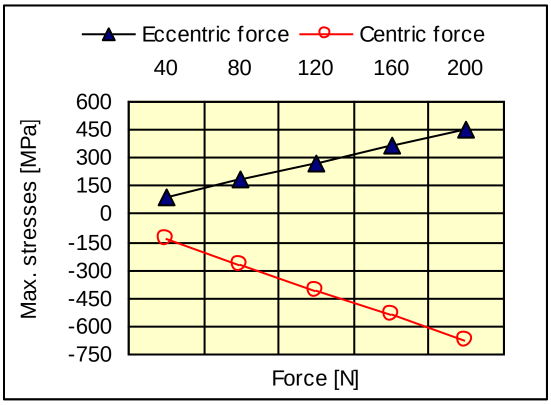

Figure 10. Maximum values variation of Von Mises stress in the concentrator at various values of both eccentric and centric force

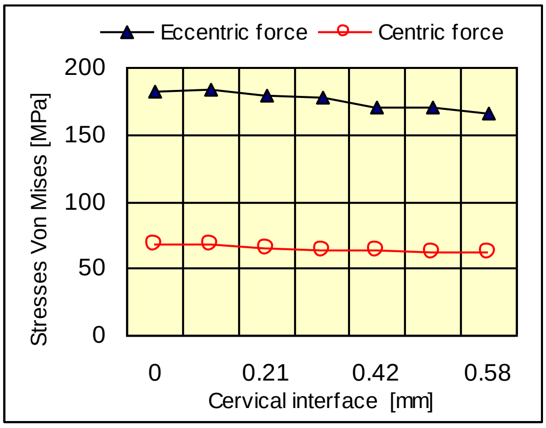

Figure 11. Von Mises stress values in the cervical area for different positions of a F=160N

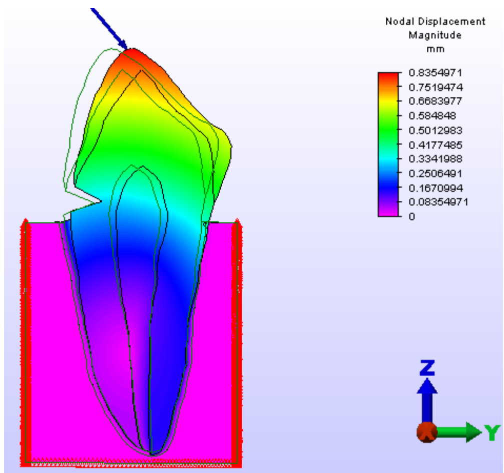

Figure 12. Displacements distribution for eccentric force of F=160N(areas of equal stress)

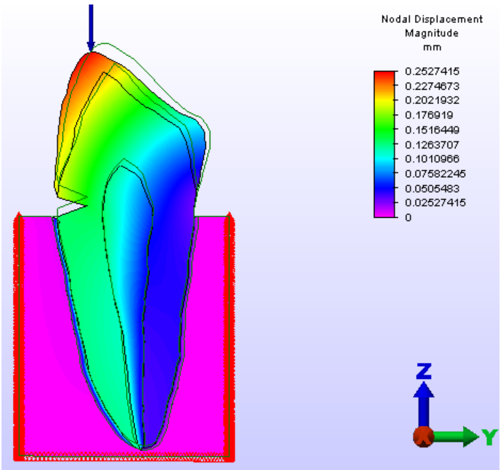

Figure 13. Displacements distribution for centric force of F=160N (areas of equal stress)

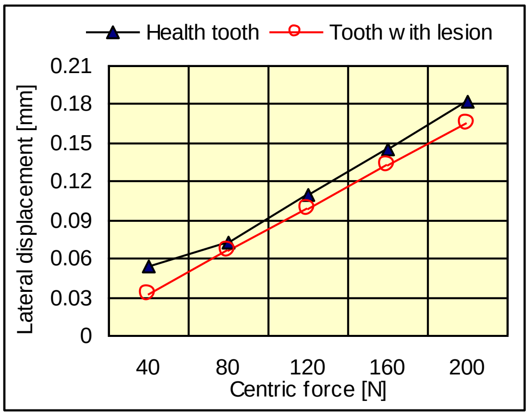

Figure 15. Comparison: intact tooth – tooth with cervical lesion for centric force
The node with maximum displacement value (0,1mm from colet)

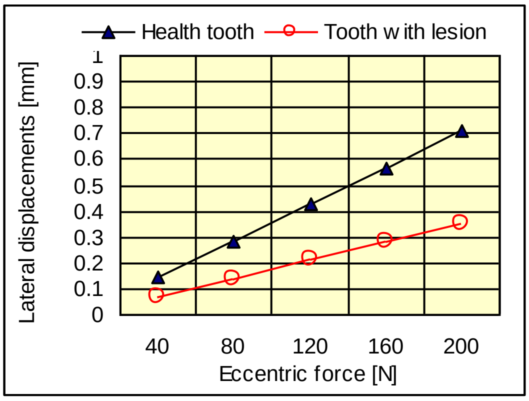

Figure 14. Comparison: intact tooth – tooth with cervical lesion for eccentric force
The node with maximum displacement value (0,1mm from colet)

4. Conclusions

Our study has found that:

- Von Mises equivalent stress values are higher in the tooth exhibiting a cervical lesion as compared to the intact tooth (Fig.5. and Fig.6);
- eccentric force leads to lateral flexure while centric force leads to axial compression of the tooth (Fig.12. and Fig.13);
- displacement induced by the direction of the stress result in lateral displacement following eccentric force respectively centric displacement (compression) for vertical force (Fig.9.a, Fig.12; Fig.9.b. and Fig.13);
- stress values within the lesion are higher for eccentric force;
- different stress profiles lead to different phenomena within the tooth: tensile phenomena for eccentric force, respectively compression for centric force;
- the bottom of the lesion is exposed to maximum values of the stresses thus becoming a stress concentrator (Fig.7. and Fig.8);
- maximum stress values in the bottom of the lesion increase with strain (Fig.9);
- maximum stress values in the bottom of the lesion are positive for tensile force and negative for vertical force (Fig.7., Fig.8. and Fig.10);
- stress concentration in the bottom of the lesion will lead, in time, to cracks which will eventually affect the whole structure;
- stress concentration in the bottom of the tooth constitutes major risk for abfraction.

An abfractive lesion constitute a stress concentrator who leading to cracks and their propagation into the tooth ultimately leading to fracture. Once this has occurred, there seems little to prevent the process from beginning afresh.

5. References

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