ORIGINAL ARTICLE

Biomechanism of Abfraction Lesions

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Introduction: Caries and dental trauma are mostly responsible for the loss of hard tooth tissue. However, other destructive processes that originate on the external surface and affect the teeth and cause irreversible loss to the tooth structure are also described such as erosion, abrasion, attrition and abfraction.
Objective: The purpose of this study was a finite elements method study of the mechanism of abfraction formation caused by external loads.
Material and methods: A two-dimensional mathematical finite elements analysis model was generated for analysis, using intact normal human mandibular canine. The finite elements are type of 2D. A denser mesh with a large number of EF was build in the area of interest in order to obtain the best replica of the tooth and the most faithful analyses of the situation.
Results: As a result of the present study using simulations of different values and positions of the loads, both vertical and oblique, on a healthy tooth, it was evident that the most stress-prone area with the highest risk of mechanic damage is the cervical area of the tooth.
Conclusions: Oblique loads lead to lateral flexure of the tooth and vertical loads lead to axial compression. Vertical direction of loads result in higher values of the stress in the lesionned area. The study shows that one of the possible causes of cervical lesion is the direction and magnitude of loads combined with the morphology of the tooth in question.

Keywords: finite element method, abfraction, load, stress

Introduction

The destructive processes that originate on the external surface and affect the teeth and cause irreversible loss to the tooth structure are described such as erosion, abrasion, attrition and abfraction. The term dental erosion is used to describe the physical result of a localized, painless, chronic, pathological loss of hard tooth tissue causes by acid attack, without the involvement of bacteria [1]. Abrasion lesions originate from the pathological wear of the hard tooth tissue through abnormal mechanism processes that involve foreign substances or objects introduced repeatedly into the mouth that come in contact with the teeth. The term dental attrition is used to describe the physiological wear of the hard tooth tissue as a result of the contact between one tooth and another, with nothing foreign interposed between them. The term of dental attrition is used to describe the physiological wear of hard tissue [2]. The term of abfraction, derived from de Latin verb frango, frangere, fregi, fractum meaning to break, to crush, describes a special type of wedge shaped defect in the cervical region of the tooth [1,2]. 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 clinical values being considered of 70N [1]. One of the possible factors leading to noncarious cervical lesions (NCCL) is the mechanical factor determined by the magnitude and position of the occlusal loads vectors distributed on each tooth [3].

The mechanical mechanism of NCCL formation can be efficiently simulated using FEM method, nowadays one of the most effective methods to analyze structure of the tooth and the mechanical phenomena, irrespective of complexity, shape or materials.

The purpose of this study was a FEM study of the mechanism of abfraction formation caused by external forces.

Material and methods

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

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). Longitudinal elastic modulus (Young modulus) and Poisson's ratio values for the materials used in the model were derived from standard texts (3).

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 build in the area of interest in order to obtain the best replica of the tooth and the most faithful analyses of the situation. To simulate material continuity, all the parts of the dental structure are considered connected and forming whole body.

Two situations of tooth loading were considered:

a. Oblique nodal stress at 40 degrees to vertical applied onto the vestibular aspect at h=8.993mm from cervical area of increasing magnitudes: 40, 80, 120, 160, 200N (Figure 3a);

b. Vertical nodal stress of increasing magnitudes: 40, 80, 120, 160, 200N applied onto the tip of the tooth (Figure 1).

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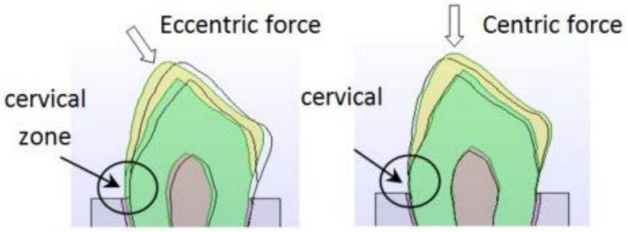

Fig. 1. Schematic diagram of tooth flexure creating cervical stresses

The stresses 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.

The study sets off from the working hypothesis that there are various differences in stress profile between healthy teeth and teeth with cervical enamel damage.

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 receiving most of the stress thus becoming prone to mechanical damage expressed in abfractions.

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

- equivalent stress Von Misses;
- stress following tooth direction Z-Z;
- main minimal stress (compression effect);
- resultant displacement.

The results obtained after simulations on a tooth lesioned on the cervical area were compared to the results obtained following simulations on a healthy tooth.

The same values were considered of significance both for the healthy and lesioned tooth.

Model I. Healthy tooth – lesion mechanism

As a result of the present study using simulations of different values and positions of the loads, both vertical and oblique, on a healthy tooth, it was evident that the most stress-prone area with the highest risk of mechanic damage is the cervical area of the tooth. A maximum stress at 0,1mm above the cervical line for an oblique load was noticed (Figure 2).

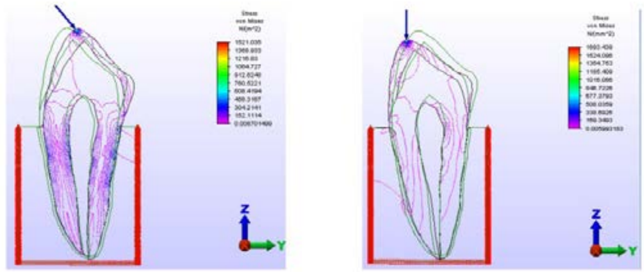

Fig. 2. Von Mises equivalent stress distribution. Curves of equal value corresponding to a tensile and vertical loads of F=160N

The variation graphs for the stress values of the various forces applied on the cervical area were created (Figure 3).

Model II. Tooth with cervical lesion

Loads of different positions and magnitudes applied on a tooth with cervical lesion will lead to a increasement of stress in the area. The lesion will become a stress concentrator with fissures propagating onto and into the tooth, ultimately leading to tooth fracture (Figure 4).

Displacement induced by the direction of the stress result in lateral displacement following tensile load, respectively vertical displacement (compression) for vertical load. Different stress profiles lead to different phenomena within the tooth: tensile phenomena for tensile load, respectively compression for vertical load.

The bottom of the lesion is exposed to maximum values of the stresses thus becoming a stress concentrator maximum stress values in the bottom of the lesion are positive for tensile load and negative for vertical load (Figure 5).

Discussions

The term abfraction is used to describe a special type of defect in the shape of a wedge in the cervical region of a tooth. There is a hypothesis that these lesions, generally found in a single tooth or in non-adjacent teeth, are the result of

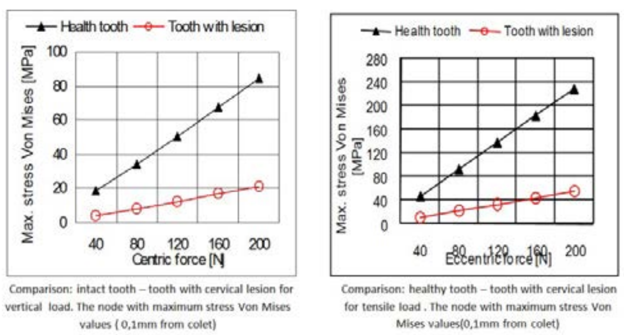

Fig. 3. The node with maximum stress Von Mises for tensile and vertical loads

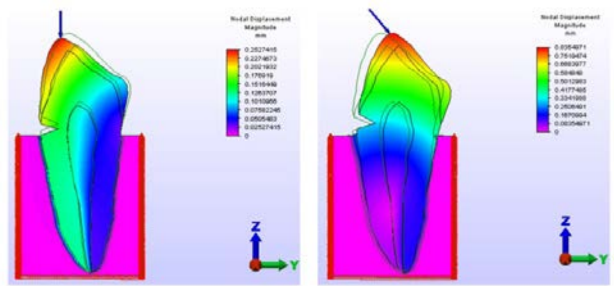

Fig. 4. Displacements distribution for tensile and vertical loads of F=160N (areas of equal stress)

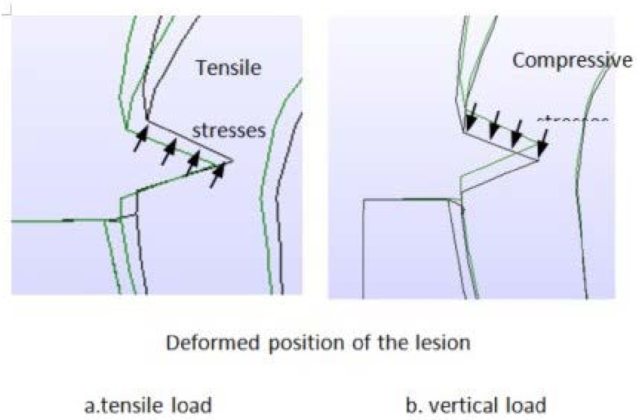

Fig. 5. Deformed position of the lesion

Occlusal forces eccentrically applied, leading to the flexing of the tooth, and are not only the result of abrasion [2]. According to the theory of tooth flexure, parafunctional forces in areas where interferences occur, principally lateral areas, can expose one or more teeth to strong tensional, compressive or shearing pressure. These forces are focused in the cementoenamel junction, which caused microcracks in the enamel [1]. It is believed that, with time, the microcracks spread perpendicularly along the axis of the teeth under pressure until the enamel and the dentin are broken [4]. The resulting defects, in the form of a wedge, have sharp edges and are, as pointed out, more frequent in isolated teeth. They are also frequent in teeth that already have restorations in the cervical region [5].

Our study is based on the golden rule in engineering according to which any stress will always fallow the direction of the most rigid material, that is to say, of the material with the highest elastic modulus.

The results show that from a mechanic stand point, the maximum strain appears in the cervical area at 0.1 mm above the cervical line, irrespective of load direction. This is the area were the tooth is most exposed to flexure leading to a concentration of stress which increases with the Occlusal forces, ultimately leading to fissures. As a result of load direction on the tooth, a stretching of the tooth appears at oblique loads and a compression of the tooth appears at vertical loads; the phenomenon determines positive maximum strain values in the bottom of the lesion (stretching strain) at oblique loads respectively negative maximum strain values in the bottom of the lesion (compressive strain) at vertical loads.

Conclusions

Based on the results obtained, the following conclusions appeared:

1. maximum stress values are obtained onto the cervical area, at 0.1mm from colet;
2. cervical area stress values increase with occlusal stress;
3. von misses equivalent stress values, for the same value of the stress, are higher in the tilted position of the stress;
4. different stress profiles lead to different phenomena within the tooth: tensile phenomena for tensile force, respectively compression for vertical force;
5. the bottom of the lesion is exposed to maximum values of the stresses thus becoming a stress concentrator;
6. stress concentration in the bottom of the tooth constitutes major risk for abfraction.

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.

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.

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