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EVALUATION OF PERI CERVICAL DENTIN STRESSES WITH TRUSS ACCESS CAVITY AND TRADITIONAL ACCESS CAVITY IN MAXILLARY FIRST MOLARS – A FINITE ELEMENT ANALYSIS

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ABSTRACT

Aim: The aim of this study was to compare the peri cervical dentin stresses of the maxillary first molar with Truss and Traditional access cavities using the finite element method. **Methods**: Finite element analysis models of a maxillary first molar were designed and constructed with different types of endodontic access cavities: **Group 1:** Traditional Access Cavity. **Group 2:** Truss Access Cavity. Each model was subjected to two different force loads directed at the occlusal surface. The stress distribution patterns and the maximum Von Mises (VM) stresses were calculated and compared. **Results**: The peak Von Mises stress on all models was at the site of the force load. The occlusal stresses were spread in an approximate actinomorphic pattern from the force loading point, and the stress was much higher when the force load was close to the access cavity margin. The area of peri cervical dentin experiencing high Von Mises stress increased as the cavities extended. Peak Von Mises stresses at peri cervical dentin was seen in traditional endodontic access cavity. **Conclusions**: The inference drawn under the restraints of this study are, the Truss access cavity showed low-stress concentration compared to Traditional access cavity. With enlargement of the access cavity, the stress on the peri cervical dentin increased significantly.

INTRODUCTION

A predictable treatment outcome and successful long-term retention of the root canal-treated teeth are the primary goals of modern endodontics.[1]

Successful root canal treatment depends on the adequate debridement and filling of the entire root canal system. In the due course of achieving this, dentists overzealously prepare the access cavity and canals in order to clean the root canal.[2]

Research has revealed traditional access cavity preparation may result in weakening of the remaining tooth structure added to the previously weakened structure because of pathology. This could be attributed to the loss of strategic internal tooth architecture at the centre of the tooth and/or the marginal ridges, which may manifest in the form of cuspal deflection.[3]

To address this, Clark and Khademi redesigned the endodontic access cavity design and called it the Conservative Endodontic Access Cavity to reduce the amount of tooth structure removed. The cavity design is sought to protect the peri cervical dentin and a portion of the chamber roof.[4]

Peri cervical dentin (PCD) is the dentin that is located 4 mm above and 4 mm below the crestal bone which serves to distribute the functional stresses in teeth. No man-made material can replace PCD.[4]

Truss Access Cavity on the other hand has been recently introduced to further preserve the tooth structure. The prime objective of these access cavity designs is strategic dentin preservation i.e., leaving a truss of dentin between the two cavities thus prepared. Cone beam computed tomography information of the tooth together with magnification is used to prepare strategically located truss access. These accesses are placed directly above the respective root canals, and through these holes, cleaning, shaping, and obturation is performed. Hence, complete root canal treatment (RCT) is performed either through existing restorative cavities or by creating small entries leaving lateral pulp horns and the rest of the pulp chamber unroofed. It remains to be verified if such access designs hold a significant advantage in the clinical situation.[5]

FEA is a computerized method for predicting the behaviour of products that are subjected to a variety of physical stresses and vibrations, as well as fatigue and motion. It converts real objects into many finite elements in the form of small cubes. It is a useful tool to

investigate complex systems and has been widely applied to endodontic stress analyses. Knowledge of the stress distribution is important for understanding fatigue development.[6]

FEA studies comparing the effects of Traditional and Truss access cavities on fracture resistance of Endodontically treated tooth have not yet been reported in literature. Therefore, the aim of this study was to compare the peri cervical dentin stresses of Traditional access cavity and Truss access cavity designs in the maxillary first molar using FEA.

METHODOLOGY

Selection of Tooth and Modelling of Maxillary First Molar

Human maxillary first molar with fully formed apex of a healthy individual was chosen for this study.

- The first step in the finite element analysis is **modelling**. The quality of the analysis results depends on the accuracy of the model.
- A three-dimensional mathematical finite element analysis model was generated for analysis; by CBCT– Planmeca Finland using CS3D software, operating at 90 kV, 12 mA with a voxel dimension of 75 μm generating a total of 668 images that were stored in a DICOM format.
- Images were then processed using the materialize interactive medical image control system (**MIMICS** 19.0; Materialise, Leuven, Belgium) to identify enamel and dentin, then produce three dimensional (3D) objects by forming masks and automatically growing threshold regions (110kVp, 1.98mA, 3.6s, 9inch field of view and 0.3 mm resolution).
- All the dimensions of hard tissues were noted.
- The data obtained was fed to the computer and using software **MIMICS** (Materialise Interactive Medical Image Control System) was converted into a three-dimensional model.
- Different parts of the tooth including dentin, enamel, cementum, periodontal ligament, and alveolar bone were designed. The maxillary alveolar bone that supports the tooth was also reconstructed.
- Thus, a virtual model of maxillary first molar with its supporting structures was obtained.

Dimensions of the Virtual Cavity

Virtual access cavities will be prepared in the following access cavity designs.

- **Group 1: traditional endodontic access cavity.**

Traditional endodontic cavity was prepared in such a way that entire roof of pulp chamber will be removed and a straight-line path created from the access opening to the coronal part of canal. The shape of access cavity is triangular.

The walls were coronally divergent to visualize the pulp chamber floor and all the canal orifices.

- **Group 2: Truss Endodontic Access Cavity**

The prime objective of these access cavity designs is strategic dentin preservation (ie, leaving a truss of dentin between the 2 cavities thus prepared).

In maxillary molars the mesio- and distobuccal canals are approached through one cavity and the palatal canal through another.

Meshing

The meshing of the finite element model is the next step. All models were imported into Cosmos software package (Solid works software package, Dassault Systems, Cedex, France) for meshing. The finite element model was divided into several finite elements. The elements chosen for the study was **tetrahedral.** The solid model was filled with elements creating the mesh, and the properties of enamel, dentin, cementum, periodontal ligament (PDL) and bone were assigned to the elements, which filled the corresponding regions.

The elastic properties namely the young's modulus and the Poisson's ratio were defined for different parts of the tooth, restorative materials filling the cavity designs and the neighbouring anatomical structures. Thus, finite element models of teeth were realized by changing the element material properties in the zone of cavity preparations.

Table 1: The Mechanical Properties of the Investigated Materials.

Material	Elastic Modulus (MPa)	Poisson Ratio (μ)
Enamel	84,100	0.33
Dentine	18,600	0.31
Pulp	0.2	0.45
Cortical bone	13,700	0.3
Cancellous bone	1370	0.3
Periodontal ligament	689	0.45
Gutta-Percha	0.69	0.45
Composite resin	12000	0.3
Flowable composite resin	5100	0.27
Cement layer	6000	0.3

To simplify the development of the FEA model, following assumptions with material properties were considered in the analysis.

- The cement material between the gutta-percha and dentine was simplified due to the negligible thickness of the cement material and the cement was considered to be part of dentine.
- Flowable and hybrid composite resin were used for the access filling.

Loading Conditions

The loading processes were as follows:

1. The models received a vertical occlusal force at a constant intensity of 250 N to simulate a normal vertical mastication load. The load was applied to the central groove area of the model.[1]
2. A total force of 800 N was applied to 5 different points as the pressure load to the occlusal surface to simulate the maximum mastication force.[1]

The distribution of von Mises (VM) stress on the models were obtained, tabulated and graphically presented.

RESULTS

Under the different force loads, the distributions of peri cervical VM stress on the Truss Access Cavity were much lower than in the Traditional access cavity model [Graph 1]. Under the vertical force of 250N, the peak VM stress in both models occurred at the central groove. For the Truss Access Cavity, the peak stress was 27 MPa while that of Traditional access cavity was higher (33 MPa). Under vertical load of 800 N, the peak VM stresses on the Truss Access Cavity and Traditional access cavity were 120 MPa and 141 MPa, respectively.

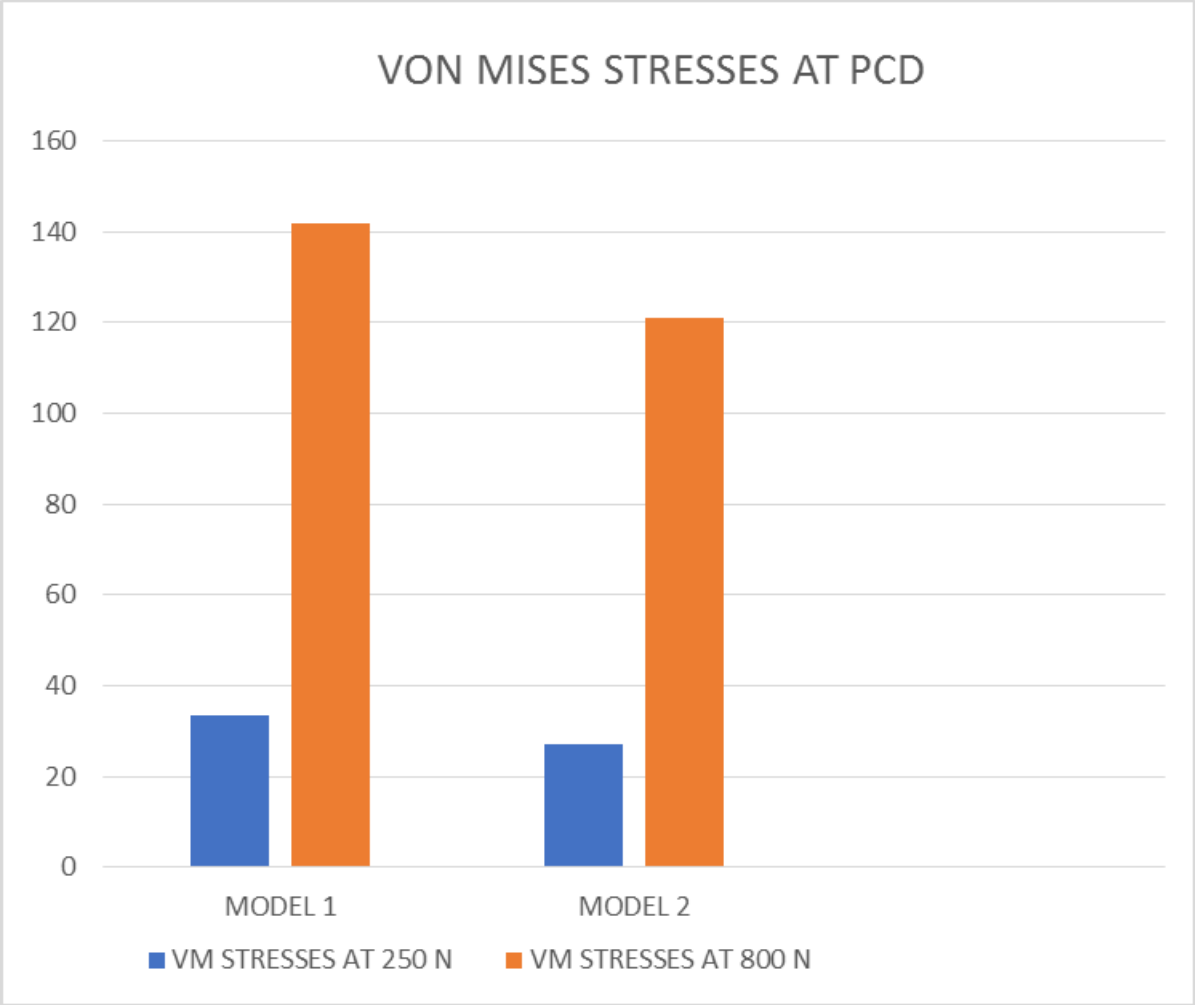

Figure 1:

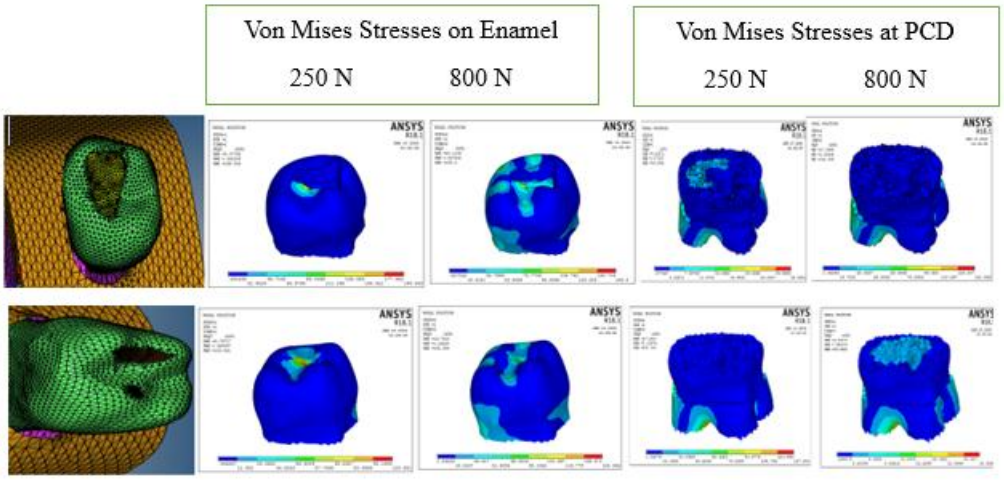

Figure 2:

DISCUSSION

One of the major causes of fracture in endodontically treated teeth is loss of coronal tooth structure, resulting from both dental caries and the preparation of the endodontic access cavity. The amount of dentin lost through the access cavity design plays a significant role in this phenomenon. There is a direct link between the volume of dentin lost and the specific access cavity design.[7]

Burns stated the maxillary first molar to be "the frequently treated, minimally apprehended, posterior teeth". The priority in the study was to use mature and unharmed upper first molars to eliminate the influence of different levels of tooth structure loss. In this regard, this study sought to evaluate and compare the peri cervical dentin stresses of endodontically treated teeth in traditional and truss access cavity. The available data on fracture resistance of maxillary molars are lacking and most of the documented fracture resistance studies were done on premolars or mandibular molars. The upper first molars were chosen for the study because they are the second most frequently affected teeth by decay and play a crucial role in mastication.[8]

Truss Access cavity preserves both the marginal ridges and a portion of the roof of the pulp chamber which provides a continuous chain of strength. It is believed that strategically important dentin is retained.

The study used Finite Element Analysis (FEA) to limit variables and standardize the analysis. Unlike in vitro studies, FEA allows researchers to apply various stresses to the same tooth specimen without causing actual damage, providing unlimited opportunities for analysis. It provides a clear 3D analysis for areas of stress concentration.[9]

A 3D model was created, which included various components, such as dentin, periodontal ligament, bone, cementum, gutta percha, and composite. The study considered various loading conditions, and the geometric models were constructed using the ANSYS analysis package.

The masticatory forces studied via simulation were 250 N and 800 N. 250 N was applied at the central groove to simulate normal masticatory forces. A maximum masticatory force of 800 N at 5 different sites on occlusal surface of the models were applied which simulated the real chewing situation. Von Misses (VM) is a theoretical measure of stress in FEA used to estimate fracture.

In this study, all the materials, including the tooth and its supporting structures, were treated as homogeneous and isotropic materials. Two important elastic properties viz., Modulus of elasticity (MOE) and Poisson's ratio (PR) are taken into consideration in all FEM studies. In this study the elastic modulus and Poisson ratio values for the tooth and its supporting structures were in accordance with the previous studies.

VM stress at peri cervical dentin at 250 N and 800 N was highest in Traditional Access cavity followed by Truss Access cavity.

The peak VM stress in both models occurred at the sites of the force load, and the VM stress on the occlusal surface was spread in an approximate actinomorphic pattern from the load point. As the cavity margin approached the load points, the VM stress increased dramatically. In both the groups i.e., 250 N and 800 N, highest occlusal stresses were at Traditional access cavity group. According to the occlusal stress nephogram, the spread of Von Mises (VM) stress from the composite resin was found to be smaller than the spread of stress from the enamel. Despite the fact that composite resin is less rigid than enamel, the latter can handle greater stress. This could be due to the higher elastic modulus of enamel, which allows it to better handle elastic deformation than composite resin.[2]

An in vitro study done by Zhang et al. has shown that teeth with truss access showed a restorable type of tooth fractures while those with conventional access showed catastrophic tooth fractures.[10]

In contrast, Corsentino et al. reported that there was no difference in the resistance to fracture between truss and traditional access preparations. This disagreement could be due to the difference in methodology as their study was in vitro and lacked standardization of the size of the truss access.[11]

The benefits and possible drawbacks of the conservative endodontic access cavity concept have not been well supported by research data.

Despite the fact that truss access is supported by the study's findings, this type of design has some practical drawbacks. The truss access compromises the instrumentation and debridement of the root canal. It has been noted that after conservative access preparation, there are deviations from the original canal anatomy.[12]

Therefore, Finite Element Analysis (FEA) only offers a broad overview of the biomechanical properties and fracture risk evaluation of molar teeth with various access cavity designs. Further research, such as in vitro studies that recreate clinical scenarios and in vivo studies, is necessary to establish the connection between the numerical values and actual clinical outcomes.

CONCLUSION

Within the limitations of this study done using Finite element analysis it can be concluded that under all the loading conditions Truss Access cavity showed least VM stress as compared to Traditional access cavity

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