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A 3d Analysis of Influence of Canal Preparations on the Fracture Resistance of Molars- An Original Research

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Abstract

Introduction: The success of the root canal therapy depends on many factors. Loss of the tooth structure during the canal preperation leads to the fracture of the tooth. The rotary instruments were invented to put less force on the tooth during the preparation.

Hence in the present study we aim to compare the effect of three rotary file systems (Vortex Blue, VTaper, ProTaper,) with dissimilar tapers on fracture resistance of root canal treated teeth by various static and dynamic forces applied to different parts of the coronal part of teeth.

Materials and Methods: 3D printed acrylic maxillary first molar was used. The original geometry was changed and primed for using Spaceclaim software for ANSYS modeling and analysis. The three experimental groups and one control group were created. Group one was ProTaper, group two was Vortex Blue and group three was V-Taper. Young modulus and Poisson ratio of all the materials (Enamel, Dentin, Gutta-Percha, Composite) were used for ANSYS software to recognize these volumes and the constituents that are contained within these individual spaces. In this study seven total contact points were considered on the occlusal surface of the models during the chewing cycle. The Von Mises stress and maximum principal stress on the cervical region were calculated and investigated in four different cross sections of pre cervical dentin.

Results: The highest Von Mises stress was observed in the ProTaper group although V-Taper and Vortex Blue groups showed homogeneous stress distributions in the cervical regions as well. Tensile stress was concentrated on the palatal side of the palatal root and the distal portion of the distobuccal (DB) root in all the experimental groups. However, the control group had the least

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amount of stressed area followed by V-Taper group, Vortex Blue and ProTaper.

Conclusions: Taper size of endodontic files seems to affect the distribution of forces along the root structure. Preserving dental hard tissue in precervical dentin significantly reduces the stress concentration in the cervical region and increases the eventual fracture resistance of the tooth.

Keywords: Root canal preperation, root fractures, Taper of the file, Rotary instrumentation

Introduction

Fracture of the Root is the third most common problem for the tooth loss only after caries and periodontitis. (1) For the clinical practice the knowledge of the biomechanics of the fracture is important for the successful treatment. The initiation and the propagation of these fracture lines can be a result of the various types of the forces.(2) The loss of the major portion of the tooth due to the preperation for the root canal may lead to the concentration of the forces and may help in the fracture propagation.(3) To avoid this, removal of the pre-cervical dentin excessively is to be avoided. (4,5)

Various rotary systems apply various types of the file systems that use files of different cross sections, sizes and shapes that have different working patterns once inside the canal. There are many studies that have described the root fractures when these rotary instruments are used. (6–8). In the study of Clark and Khademi, they have suggested that the pre-cervical dentin be protected at all the times to prevent the fracture.(9). Most of the studies done previously are studied invitro. This is because as the human teeth are tough for the standardization. (10)

Hence in our study we used FEA (Finite Element Analysis) to gain a better understanding of the effects of the cleaning and shaping process through endodontic treatment. FEA would also help in knowing the factors for initiation and propagation of cracks and fractures in root canal treated teeth. Thompson et al, stated that during the mastication, the stress at the cervical region of the tooth rises as the taper of the files increases (11). In our study we compared three commonly used files systems. V-Taper, Vortex Blue, and ProTaper are used to understand the fracture resistance after the root canal preperation to the various strains and stresses at different parts of the tooth.

Materials and methods

3D printed acrylic maxillary first molars were used in the study. For the FEA, CAD geometry of the tooth was first prepared. The replica was then scanned by a micro CT. The image was sent to the ANSYS SpaceClaim software for analysis. All the precautions were taken to simulate the original tooth morphology of the molar. We classified the replica into 4 groups. They are Group1- ProTaper, Group 2 - Vortex Blue, Group 3 - V-Taper, Group 4- Control. A conventional access cavity was made with one-degree inward taper to the pulpal floor. Canals were then prepared and designed starting at the pulpal floor and extending to the apex. The apical foramina were enlarged to 0.3 mm, and the working length was set at 0.5 mm coronal to the apical foramen. 16 mm was the length of the canals. Later the canals were filled with the GP obturating materials. Access cavity was restored with composite in the three groups. For the control group the canals were left empty and the access was filled with 2 mm of enamel and the dentin. All the materials were noted for the physical properties. The amount of the loads was

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thoroughly registered. Von Mises stress was calculated in each of these elements. All the replicas were subjected to similar stresses and strains that are produced in the routine mastication. All the volumes and the amount of the displacements faced by all the replicas under similar conditions were registered. The obtained values were only compared between the groups.

Results

The Von Mises stress and maximum principal stress on the cervical region of maxillary first molar replica is calculated. In this study, the cervical region was deliberated as a critical zone. The stress distribution of the chewing force was deliberated and analyzed in four separate horizontal cross sections of the cervical region. Three cross sections were located above the pulpal floor and one below the pulpal floor at the level of buccal furcation. Von Mises stress was more at the CEJ level. The highest Von Mises stress was observed in the ProTaper group, although V-Taper and Vortex Blue groups presented homogeneous stress distributions in the cervical regions as well. The stress distributions of the maximum principal stress in the cervical region were analyzed. The ultimate loads that caused failure of dental material was considered to be 50 MPa and any amount of stress higher than that was revealed in red in all the experimental group, and it was considered detrimental to the tooth structure.

In all experimental groups, tensile stress was concentrated on the palatal side of the palatal root and the distal portion of the distobuccal root in the cross sections at the level of CEJ and the pulp chamber floor (Figure 13-14). However, the intensity of stressed areas differed among each experimental group. The control group had the least amount of stressed area in red followed by V-Taper group, Vortex Blue and ProTaper

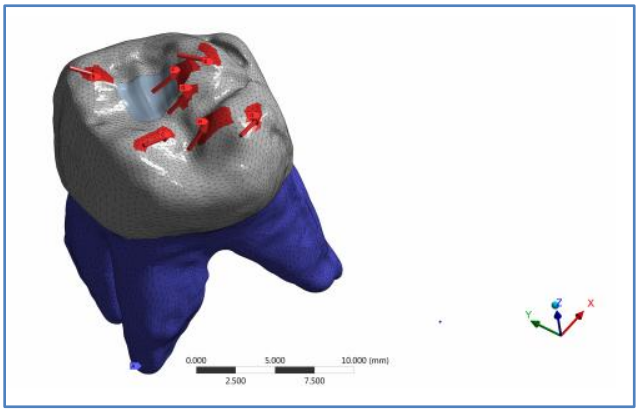

Figure 1: Schematic diagrams of the finite element models and load location. Red areas indicate contact points during chewing cycle. Purple illustrates the location of alveolar bone.

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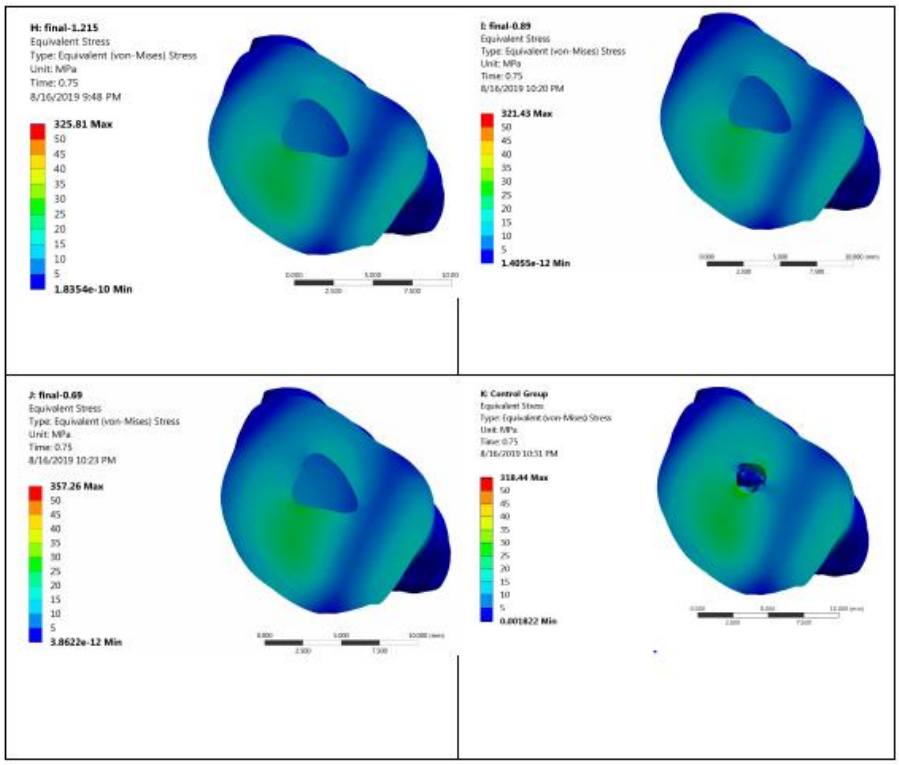

Figure 2: Concentration of the stresses as noted in the FEM.

Table 1: Comparison of the various canal preperation systems

Distance from CEJ	Protaper	V-taper	Vortex blue	Control
2.5 mm above the CEJ	325.81	321.43	357.26	318.44
0.3 mm above the CEJ	325.81	321.43	357.26	318.44
1.3 mm above the CEJ	325.81	321.43	375.26	318.44

Discussion

In the study of Kakehashi et al, they proposed that the microorganisms were the cause for the dental diseases. (12) In the root canal treatment the removal of these microorganisms will help in the healing of the tissues surrounding the periapical region. Many modifications have been made in the treatment modalities of the root canal therapy with the advent of the rotary instruments. Various studies state that the instrumentation by itself can efficiently reduce the microbial load in the root canal system by 90 % (13). But there has been no one particular instrument to fully achieve this sealing ability.

With the usage of the various rotary systems there has been much comparison of how these may impact the strength of the tooth in the long run. It has been stated in the study of Hedge et al, that the preperation of the root canal should follow the anatomy and remove as less tooth structure as possible.(14) In the various studies of Orstavik et al, Peters et al the final preperation sizes and the instrumentations had no significant variations on the outcome.(15,16). The best size of the

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file that can bring about an ideal outcome is yet to be determined.

It is imperative to the clinician to not only understand the mechanics of the instruments but also to the impact of these on the strength if the tooth. With the recent rotary systems there has been a noted removal of the tooth dentin in the coronal and the radicular areas. In the study of Gher et al and Kovac et al, they have noted higher ratio of vertical root fracture in endodontically treated teeth (17, 18). Teeth that have been fractured may not been noticed for a long time by the patient and the pain may only be felt under specific conditions. Hence it is challenging for the dentist to identify and diagnose these fractures. Therefore many attempts to minimize the instrumentation as much as possible are done. If the tooth fractures while eating then the effort that was done to endodontically restore it may go in vain.

Hence in the present study we intend to compare the fracture resistance of the tooth while conserving as much as tooth possible. Maxillary first molar CAD design was used to simulate the natural masticatory forces. We selected the rotary instruments with different sizes and tapers.

The FEA was used to measure the amount of stress and strain applied on dentin near the pre-cervical area and alveolar crest of maxillary first molars. It is a critical zone that is roughly 4 mm above the crestal bone and extends 4 mm apical from the crest of the bone.

We selected the pre-cervical area as it has the: 1) The effect of ferrule, 2) the proximity of dentin tubule orifices at the CEJ, 3) the significant reduction in enamel thickness, and 4) the concentration of all masticatory forces in this area (5-11). In this study, a replica of the maxillary first molar that is endodontically treated with three different rotary instruments was generated based on micro CT.

We noted that, Von Mises stress was more on the margin of the palatal root significantly less in the V-Taper group and the control group in contrast to ProTaper and Vortex Blue. With the reduction of dentinal wall removal, the stress concentration also declined.

The ProTaper group showed the most amount of stress concentration surface area in comparison to the other groups at the CEJ level, and with the V-Taper group having the closest stress concentration to intact tooth. The foci of tensile stress were located on the palatal portion of the palatal root, the root furcation, and the distal portion of the distal root. Previous studies have shown that the maximum principal stress in the mesio-buccal root was significantly more than other areas (19).

Nevertheless, in this study, the maximum stress was on dissimilar areas possibly due to the replication of the chewing forces rather than using direct vertical forces.(20-22) The three groups of file sizes in this study had same tip size (0.25 mm), yet, their MFD at D16 are significantly different, with ProTaper being the largest file and V-Taper being the smallest near D16. Hence, within the limits of the present study, it can be stated that saving the dental hard tissue, in particular pre-cervical dentin, in root canal therapy is a feasible method to decrease the maximum principal stress and to decrease the stress concentration near this susceptible area. This was a critical area to scatter stress through the long axis of the teeth.(23-25) V-taper files are intended to decrease the amount of tooth structure removal in pre-cervical dentin to minimalize the overall weakening effects of endodontic treatment.

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Conclusion

In our study we intended to explain the taper of the instrument and the fracture resistance by using the Finite Element Analysis in the maxillary first molar replica. We can conclude that Taper size may effect to the fracture resistance in the cervical areas by concentration of forces. Conserving dental hard tissue will decrease the concentration of the stress in the cervical region and hence may prevent the tooth fracture. However the simulated FEA method has few limitations. Thus, the clinical implications of results obtained in our study need additional exploration on natural tooth and ideally under masticatory forces in the oral cavity.

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