Study Protocol

Effect of restorative crown of different cuspal inclination and occlusal contact on stress distribution in mandibular second premolar with different ferrule configuration and peripheral bone- 3D finite element analysis

Abstract

Background

Restoration of pulpless teeth have been difficult because of coronal loss from dental caries, diminished moisture content, endodontic therapy and fractures, resulting in prone to fracture of the tooth during function .Cast metallic band enclosing around cervical surface of a tooth is called ferrule. The role of ferrule is to assist in strengthening the endodontically treated tooth. In case of ferrule less tooth, the post performs as a wedge and may result in root fracture. Therefore modification in design of ferrule is required. Presence or absence of ferrule of coronal dentin influenced stress distribution pattern within tooth structure. Failure or success of a restoration may be influenced by on how the stress is dispersed to the tooth structure so it is essential to study the stress dispersal pattern within tooth and associated structure.

Materials and methods

A three-dimensional FE method (FEM) will be carried out for study and finite element structural analysis programs will be HYPERMESH 11 and ANSYS 18.1 software. Eight 3D models will be created to simulate endodontically restored mandibular second premolar with different coronal dentin configurations. The complete crown will be modeled with a 20-degree, 33- degree, 45-degree facial cusp inclination. The oblique force of 200 N will be executed to the buccal cusp of mandibular second premolar. Analysis of results will be done by both color-coding and numerically. By using FEA software the von Mises equivalent stress (MPa) will be calculated

Key words - ferrule , post and core, finite element analysis, cuspal angulation

Introduction

Nowadays restoration of pulpless tooth is quiet a controversial subject. Due to dental structure damage, cavity preparation and root canal procedure those teeth are weakened. (1)

Special care recommended while selecting the furthermost competent way to repair them. Cervical area of an endodontically treated tooth is most prone area for maximum stress generation due to occlusal force. (2) Post reduces stress in this area, it dissipates force along the post length. Therefore, post plays vital role in maintaining the remaining tooth structures.

Successful result with restorative dentistry can be accomplished with a understanding of the importance of occlusion and not just depending on resilient materials. The use of resilient materials may reduce the importance of an accurate occlusion, which is hazardous to the overall periodontal structure. To preserve the health of the masticatory system by managing occlusal discrepancy plays very important role in restorative dentistry. (3-5) All root treated teeth should be restored with prosthesis to protect the remaining cusps while mastication. Vertical root fracture may occur due to lateral forces which can shear the residual cusp. (6) While restoring pulpless tooth, a judgment regarding post placement is made based on the functional necessities of the tooth, the residual coronal tooth structure and the loads on the tooth. To make best use of the ferrule effect, dentist should preserve most of coronal tooth structure as while preparing pulpless teeth. To obtain determined ferrule effect the nominal height of 1.5-2 mm of whole tooth above the finish line, along the circumference of the tooth preparation required. Mechanical resistance of the tooth enhanced by dispensing forces on the residual tooth structure and thereby increasing fracture resistance by maintaining the bond of the post/core or crown to the tooth. (7)

By utilizing of 3- dimensional (3D) simulations with finite element method, the study intended to evaluate effect of occlusal contact position, type of occlusal contact and cuspal angulation on stress distribution in root treated second mandibular premolar with dissimilar ferrule configurations.

Materials and Methodology:

It is in vitro computerized study, the experiments are repeatable and design of study may be changed and modified as per the necessity. The study will be carried out using a 3D simulations with finite element method (FEM) and for 3D meshing finite element structural analysis programs will be HYPERMESH 11 and for load application and problem solving ANSYS 18.1 software.

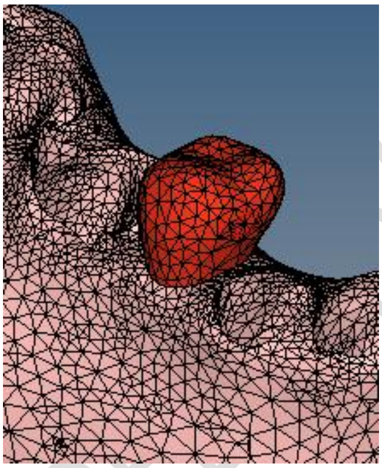

Image 1. FEA model of mandibular second premolar after meshwork

A 3D model of posterior mandibular bone will be constructed. Endodontically treated mandibular second premolar will be modelled with cancellous center bounded by 2-mm cortical bone of 16-mm width and 24-mm length (Image 1) The shape of mandibular second premolar will be acquired by micro CT (sirona scan ,belgium). The scanned profile will be assembled in 3D structure using 3D imaging software (ANSYS 18.1) by measuring root form geometry of teeth. Ceramic material used for final restoration of tooth. With 22.5 mm long tooth length and 12 mm length, 1.4 mm width of post will be modelled with Gutta-percha filling left 4 mm apically.

Comment [MM1]: 1,4mm are too much it would be better to use 1,2 or 1,0mm width post.

Loading conditions

To analyze the stress distribution, 200 N force in oblique direction is determined from the literature, angled at 45 degrees, will be executed on a smaller area of the buccal cusp to replicate the masticatory force

Material properties

2 mm thickness of porcelain fused with metal will be modelled in this study. All materials were recognized as homogeneous, linear, isotropic and elastic. Elastic properties such as Poisson ratio (μ) and Young's modulus (E) were decided from literature.(8) Eight 3D models will be created to simulate endodontically restored mandibular premolars with different ferrule configurations as follows:

Comment [MM2]: What if you selected a 0,6 or 0,8 mm monolithic zirconia crown?

1) Tooth with 4 mm remaining coronal (CC)
2) Tooth with complete circumferential 2 mm ferrule (CF)
3) Tooth with one walled buccal 2-mm ferrule (BF)
4) Tooth with one walled lingual 2-mm ferrule (LF)
5) Tooth with two walled buccal-lingual 2-mm ferrule(BLF)
6) Tooth with one walled proximal2-mm ferrule (PF)
7) Tooth with three walled buccal -lingual-mesial 2-mm ferrule(BLMF)
8) Tooth with no ferrule. (NF)

For the reconstruction of the core composite resins material were chosen, that increases fracture resistance and modulus of elasticity, also it reduces polymerization contraction, coefficient of thermal expansion and water absorption. The models treated with a post and core and a complete crown will be from 2 to 8, while the CC tooth will be treated with a single complete crown. Fiber post material assumed to be perfectly bonded to the root dentin.

Cuspal angulation

Cuspal angulation of final prosthesis will be with a 20-degree, 33- degree, 45-degree facial cusp inclination.

Location of contact

An oblique load will be executed to the bottom, middle and top of the buccal cusp.

Type of contact:

1) Surface contact (2mm diameter)

2) Point contact (0.5 mm diameter)

Expected outcome

Ferrule effect in endodontically treated tooth has positive influence on stress reduction. Occlusal anatomy and location of occlusal contact play important role in favorable stress distribution.

DISCUSSION

Endodontically treated teeth exhibited a considerably smaller service life when compared with vital teeth. The reason for failure of the endodonticlly treated teeth was reported to be prosthetic cause rather than biological, particularly for premolars with steep cusps. Approaches for minimizing the lateral forces and to improve biomechanical behavior need more scientific evidence.
Stress analysis is becoming interesting topic in dentistry for the past few decades. To investigate very irregular and complex structures, finite element method is popularly used method. Efficiency and versatility of this method already utilized in various fields like aeronautical ,civil and mechanical engineering. (2) Moreover, finite element method has extensive application in biomechanical branches like dentistry and orthopaedics.

Interpretation of the FEA results

Analysis and interpretation will be done by both numerically and color-coding. The stress in form of the von Mises equivalent will be computed using FEA software (ANSYS 18.1). All figures of maximum von Mises equivalent stress on the restored tooth and associated structure will be charted and investigated for computation of the results. Stresses in terms of von Mises yields an operative absolute magnitude of stresses, considering principal stresses in three dimensions.

In the finite element model stress dispersion represented in color coding with numerical values. Red color denotes maximum and blue represents minimum value of Von Mises stress. Yellowish red, greenish yellow, green, bluish green in the descending order represents in between values of stress distribution. (Image 2)

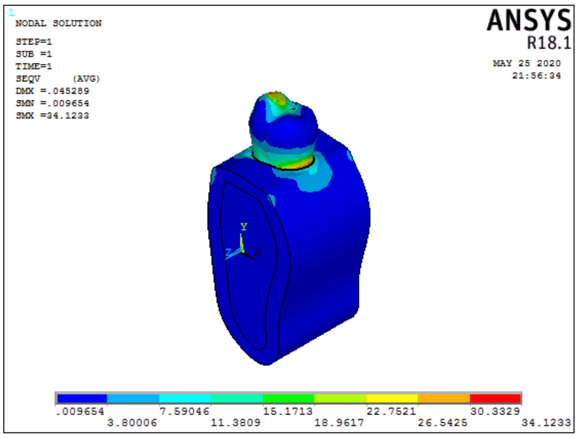

Image 2. FEA model representing color coding with numerical values of stress distribution

Von Mises measure is valid for the ductile materials which is having equivalent compressive or tensile strength. In case of materials like ceramics, cements or resin composites reported greater compressive strength than tensile strength, exhibiting brittle behavior. (14). Tensile or compressive stresses specified by positive and negative values at matching region. (15)

In case of asymmetrical loading the response of the structure will be different. Because of the higher compressive yield strength insignificant displacement seen in tooth when compressively loaded. In case of asymmetrical loading the tensile stress occurs. The tooth and associated structure are more resistant to compressive loads as compared to tensile forces which may induce a lesion in tooth structure. Lateral loads generates higher value of tensile stresses as compared to vertical loads. Due to tensile stresses, most of the failures occurred in dental materials used for tooth restoration. Very Specific occlusal modifications of teeth should be executed to avoid such events. (16)

LIMITATIONS

The precision of the simulated mathematical model of tooth and associated structures decides the accuracy of analysis. All materials are measured as homogeneous and have a linear reaction to stress contradictory to actual clinical condition. Clinically, the stress reaction to these structures to is more complex. Here obliquely applied static loads will be anticipated instead of realistic dynamic cyclic loads concentrating at tooth surface during mastication of food.

Strength

To the best of our knowledge, very few studies conducted till on this topic. This study will signify strategies for reducing the lateral masticatory forces and to improve biomechanical behavior. Importance of ferrule design will be investigated to increase longitivity of endodontically treated tooth. Further study also will be conducted by investigator and co-investigators.

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