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FIXED PROSTHODONTICS AND DENTAL MATERIALS

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STRESS ANALYSIS AND FAILURE RISK OF ENDODONTICALLY TREATED MOLARS RESTORED WITH THREE CAD/CAM MATERIALS OVER COMPOSITE CORE AND GLASS FIBER INSERTION

Rewaa G. AboElhassan[*], Dawlat Mostafa[**] *and* Noha M. Elkersh[***]

ABSTRACT

Objective: Evaluating the stress distribution pattern and failure risk of post retained crown restorations using e.max CAD), Lava ultimate, and ZirCAD restorative crown materials.

Materials & methods: Endodontically treated human molar with fiber post and composite core was digitized after CBCT, CAD software (Catia) were used to create FEA model imbedded in alveolar bone and 3 crown material: (1) EM; (2) LU; (3) ZC, A static components of 600 N loads were applied on the occlusal surface , analysis program by ANSYS 2021 were used for Finite element analysis (FEA), calculated the VMs distributions values and the total deformation values to detect the failure risk.

Results: There was difference on both VMs values at restorative crown and the remaining tooth structure and the surrounding tissues. The results showed that the greater elasticity modulus of ZC restorative material was been proportional to the higher VMs distribution values. While the lower elasticity modulus of LU was proportional to the low VMs values and remaining tooth structure. VMs values of stress distribution on composite resin core and fiber post in the ZC model were lower than LU restorative material. For the total deformation values, the risk of failure of the three models was nearly the same.

Conclusions: LU showed lower stress distribution profile and superior mechanical response that grants LU to be used as a good dental restoration.

KEYWORDS : Lavaultimate, FEA, ZirCAD, endotreated teeth, postand core .

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[*] Lecturer of Fixed Prosthodontics, Faculty of Dentistry, Alexandria University.
[**] Assistant Professor of Dental Biomaterials, Faculty of Dentistry Alexandria University
[*] Lecturer of Oral and Maxillofacial Radiology, Faculty of Dentistry Alexandria University

INTRODUCTION

Tooth decay, previous restorative procedures, or endodontic access preparation tends to weaken endodontically treated teeth due to loss of tooth structure. To prevent further damage to these teeth, a restoration must create retention and resistance. An optimal approach for construction of endodontically treated teeth in a manner that protects the remaining dental structure is the post and core.[1]

Traditionally, metal alloy post-core systems are preferably chosen for the restoration of the tooth in such status, because they are easily customized to the various shapes of the root canal and have superior mechanical strength.[2,3,4]

Many dentists prefer to use prefabricated post systems because they are less expensive, less time-consuming, and, in some situations, less invasive than customized post and cores.[5]

It is argued that these posts have an elastic modulus (45.7 to 53.8 GPa) closer to the dentin, which provides a uniform stress distribution on the post/cement/dentin interfaces and on the dental remnant structure under masticatory intermittent loading, thus minimizing the risk of catastrophic root fracture.[6,7]

However, the prefabricated posts associated with direct cores when exposed to the clinical intermittent cyclic loading are subject to gaps or debonding of the post/core interface, increasing the failure potential of this system over the clinical service (for instance, loss of retention of the assembly). Such posts might not adequately adapt to the anatomy or specific conditions of root canals (oval shape, flared roots), resulting in a larger cement line which might cause an increase in the risk of loss of post retention so the thickness of the resin cement that shows the best stress distribution is up to 0.3mm.[8-10]

Also, removing a dental structure to enable the placement of rigid dental materials devoid of mechanical behaviors like those of the tooth, the remaining tooth is weakened. The preparation of a molar for a post in relatively narrow root canals also involves a risk of accidental root perforation and fracture.[11]

Metal-free restoration has become a standard alternative treatment option due to aesthetics and metal allergies. With the advancement in digital technologies of CAD/CAM systems and the availability of ceramic blocks, alternative esthetic restorations have been introduced. Currently CAD/CAM systems allow machining of a wide range of dental materials, such as the glass-ceramics (feldspathic, leucite-reinforced feldspar, and lithium disilicate), laboratory resins, yttria stabilized zirconia and more recently the polymer infiltrated ceramic, known as hybrid ceramics. This allows the clinician to choose the best material according to the need of each clinical case.[12]

In addition, these systems allow the restoration to be designed by a particular software, which gives the dentist better control of the characteristics of the restorations, such as controlling the thickness, shape, marginal features, occlusion of the restoration, as well as thickness of the resin cement.[13,14]

Materials with mechanical properties like those of sound teeth improve the reliability of the restorative system [15]. The new polymer infiltrated ceramic material combines the properties of ceramic and polymer. It consists of a hybrid structure with two interpenetrating networks of dominating ceramic and a reinforcing composite forming the so-called double network hybrid ceramic material. One of the main advantages of this material as a new dental restorative material is the reasonable brittleness index. The material also shows lower hardness compared with traditional veneering porcelains which may better protect the opposing teeth from excessive wear and should enable more rapid machining in CAD/CAM machines. Similar creep response as enamel and low hardness grants the material lower contact stresses and good stress redistribution ability when used as a dental restoration. [16,17]

Knowledge of the stress distribution pattern within endodontically treated teeth and within crown restorations is a key factor for understanding root fracture, which is well-known problem. It has been proposed that molars restored with some crown materials are less prone to fracture.

Little information about the biomechanical performance when associating different materials for restoration of weakened endodontically treated teeth. The studies usually evaluate tooth performance under excessive loading using destructive mechanical testing. However, a non-destructive method (FEA) has been widely used as an excellent tool for analysis of internal structural performance to predict long-term failures in specific regions and provide additional data to in vitro destructive testing. The FEA allows to numerically simulating the behavior of several materials, techniques and designs and the stress distribution under specific loading. [18,19]

Combination of crown prosthetic CAD/CAM materials with preferable elastic modulus might affect the stress distribution on crown/root assembly, influencing the clinical performance overtime in endodontically treated teeth and preventing future complications like root fracture. Therefore, to evaluate the performance of different materials for restoration of endodontically treated teeth, the aim of this study was to assess stress distribution in endodontically treated teeth restored with different CAD/CAM restorative materials using the 3D FEA. The null hypotheses assumed that: 1- There is no significant difference in stress distribution among the different restorative materials, and 2- There is no significant difference in stress distribution between the different tooth parts and surrounding structures.

MATERIAL AND METHODS

Tooth preparation

This study by the aid of single human tooth for experimental purposes was approved by the Ethics Committee of Faculty of dentistry, Alexandria University /Egypt. The approval code of this study is (Ethics code number: 0602-1/2023). A situation of severely compromised molar tooth was simulated where no adequate coronal tooth structure, which has been restored with CAD/CAM restorative crown on fiber post and composite core system.

Access cavity preparation of an extracted human single lower left first molar was prepared using high-speed diamond round burs and Endo-Z burs (Dentsply Maillefer, Ballaigues, Switzerland). Complete de-roofing of the pulp chamber using sharp endodontic explorer.

The working length was determined by placing a number 10 K-file into the canals. Root canals were instrumented with K-files numbers 10-20 and enlarged by nickel-titanium rotary instruments (ProTaper, Dentsply Maillefer, USA) according to the manufacturer’s instructions. After each file, the canals were rinsed with 1% NaClO. Obturation with gutta percha (Dentsply Maillefer, USA) and sealer (AH-Plus, Dentsply Maillefer, USA) in lateral condensation technique. The specimens were kept in saline at 37°C for one week.

Post space was prepared in the distal root canal, the gutta-percha were removed from the root canals, leaving a 3-5 mm apical gutta-percha seal. The root canals were enlarged with burs included in the post system. A glass fiber post (RTD Post #1.2, St. Egreve, France) was tried in and cut to adequate length to keep 3 mm buried later in the composite core. The canal walls and the exposed portion of the coronal dentin were etched, and the bonding agent (Adper Single Bond Plus, 3M ESPE) was applied. The post was cemented using dual resin cement (RelyX ARC; 3M ESPE) according to manufacturer's instructions. Then a 3 mm-high core was built up with a resin core (MutiCore flow, Ivoclar Vivadent). Tooth prepared with reduction of 1.5 mm at buccal and lingual surfaces and 2 mm at the occlusal surface, then a 1.5 mm-high ferrule at the CEJ.

Model generation

A Dental 3D Scanner [Medit i 600(Medit Co.)] was used to scan the surface details of the post alone and the prepared tooth with cemented post. The tooth was then inserted into a wax block for cone beam computed scanning (CBCT) [Vatech green X (capital dental equipment)] to identify the dental hard tissues and pulp boundaries and to recognize them with finite element analysis (FEA) software with a tube voltage of 60 Kv, voxel dimension of 100 μm, and exposure time of 10.8 seconds.[20]

The obtained data were converted to Digital Imaging and Communications in Medicine (DICOM) format, exported and superimposed to an interactive medical image control and a reverse engineering program (Mimics Medical 20.0; Materialize NV and Geomagic Studio 12.0; Geomagic Inc) that translated the scanned data into full 3D CAD models.

The scans were processed using 3Shape Dental Designer CAD software (inLab 3D software). A composite resin core was simulated in all models to restore the coronal region. For prosthetic restoration, it was simulated a full veneered crown, designing of a three models according to the crown restorative materials: model (1) IPS e.max CAD {Ivoclar/Vivadent, Schaan/Liechtenstein (EM)}; model (2) Lava ultimate {3M ESPE, St Paul, MN, USA (LU)}; model (3) IPS e.max ZirCAD {Ivoclar/Vivadent, Schaan/Liechtenstein (ZC)}. The cementation lines were standardized with a 0.2 mm uniform film of resin cement (RelyX™ Ultimate). All parameters were standardly set including insertion axis, margin placement, occlusal and wall thickness, and cement gap Fig(1). [21,22,23]

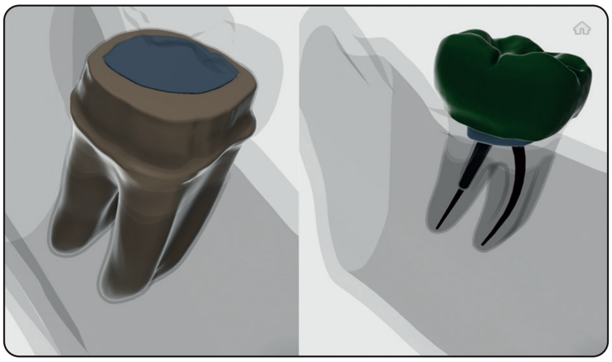

Fig. (1) showing the 3D modeling of endodontically treated lower left human molar with post and core and crown restoration.

Rapid phototyping STL data into a 3D solid model (STP format) was then reconstructed with computer-aided design software (CATIA V5R28; Dassault Systèmes).

3D model in STP file extension, containing surfaces of examined tooth were entered into finite element program by ANSYS 2021R2 (ANSYS INC, Canonsburg, Pennsylvania, United States). Points on the tooth outer surface perimeter were connected by curves which later were transformed into surfaces that enclosed the solid volume. On that basis, cross-section areas allowed creating the three solid study models of the left lower molar. A STP format of posterior mandible block (10×14×16 mm cuboid) from a patient previously recorded scanned CBCT and generated (scale of 1:1) to represent the alveolar bone (trabecular bone covered with 2mm of cortical bone) 2 mm below the margin of the restorations. The tooth was connected to the model by a 0.2 mm thick periodontal ligament. [24,25] The coordinate axis system for all the models was arranged as follows: The Z axis was directed upwards with molar long axis, while the XY plane was indicated the molar mesial, buccal and lingual surfaces Fig(2).

Mesh generation

This process provides a precise representation of the actual model's geometries. All the models were obtained from the same mesh design to prevent

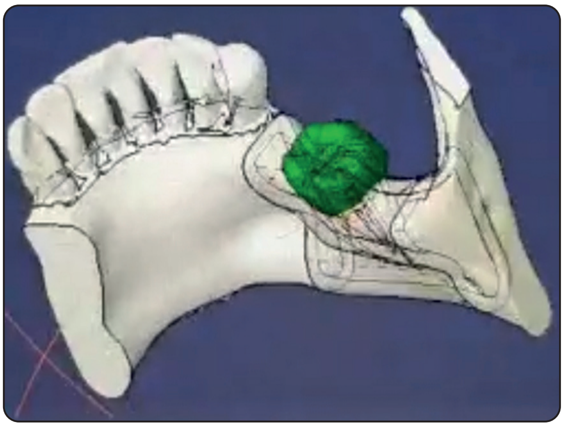

Fig. (2) Aligment of the model tooth in produced STP file of a human mandible from CBCT liberary representing cancellous bone covered with the cortical bone.

variabilities in stress levels among the models. In order to accurately achieve the actual representation, a different quadratic element (with each node containing 6 degrees of freedom) was used.

The finite element mesh was constructed using linear tetrahedral elements and the final models presented a specific number of nodes and elements (1,297,447 nodes and 891,996 elements).

Mesh refinement was based on an average Skewness factor varies between (0.21- 0.3). [26]

Boundary condition and load application

Boundary condition is an important factor in FEA, reflecting the manner of movements occurring at the nodes and their relationships. The following were considered for all models: [27]

(1) All model materials were isotropic, homogenous, and linearly elastic.

(2) FEA models were securely placed in the alveolar bone without any movement in any direction.

(3) The boundary conditions were applied on the nodes of the outer cortical bone surface to give them 0° of freedom in all the directions.

(4) No flaw was present in any of the components.

To imitate the natural 3D occlusal load, an oblique, total force of 600 N in magnitude that simulates average occlusal load was directed toward the occlusal surfaces. The oblique force is a resultant of 3 major forces, mesial, buccal and vertical forces.[28]

Materials' mechanical properties

Modulus of elasticity, Poisson's ratio of various materials were determined from published values and entered to ANSYS software including: tooth tissues, PDL, composite luting cement, and composite core, gutta-percha, glass fiber post and bone Table (1).

TABLE (1) Represents Modulus of elasticity, Poisson's ratio of various materials in the FEA models

Material	Elastic modulus (GPa)	Poisson ratio
Enamel[29]	84.10	0.33
Dentin[30]	18.60	0.32
Periodontal ligament[29]	0.15	0.45
Cortical bone[31]	13.70	0.30
Trabecular bone[31]	1.37	0.30
Resin cement[29]	7.5	0.30
Composite resin[32]	7	0.3
Gutta-percha[33]	0.14	0.45
Fiber post[32]	37	0.26
IPS e.max CAD[34]	102.7	0.22
Lava ultimate[34]	12	0.45
IPS e.max zirCAD [34]	206.3	0.32

Finite element analysis method

Computer-aided mechanical software ANSYS 2021 (ANSYS Inc., Canonsburg, Pennsylvania, United States) was used in this study. To calculate the stress patterns for different models, a linear static FEA was done. To assess the materials' strength under complex stress conditions, the maximum von Mises (mvM) stress, which constantly has a positive value, was used. Different values in various dental tissues, glass fiber post, gutta percha and composite core, and in different crown restorative materials.[28, 35]

The results obtained by solution were viewed graphically using "graphical user interface" showing VMs results. The output for each material was obtained as the color-coded diagrams where similar colors show the same range of stresses generated and warmer colors represent higher stresses.[36] After the results were calculated, midsection of all the models in mesio-distall direction were made to evaluate the stress patterns generated within the whole model. The components of the models were also separated to obtain the individual components Fig(3).

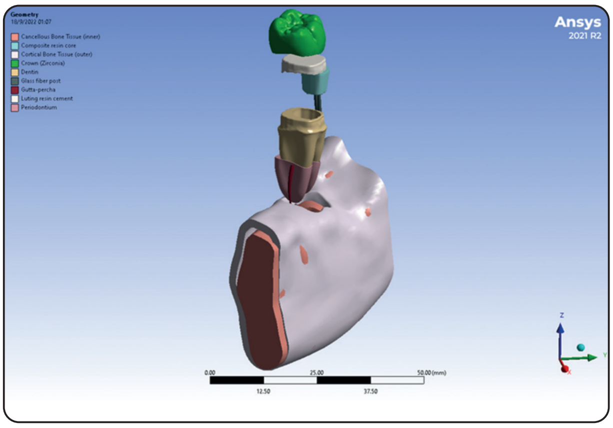

Figure (3) Evaluation of the stress patterns generated within the whole model by separatedion of each component.

RESULTS

This study concentrated on the maximum VM stress (mVM) stress values and total deformation (TD) values in different surfaces were visualized and tabulated using colour images to demonstrate stress distributions. The red zone indicates the highest stress levels, while the dark blue zone indicates the lowest stress levels Table (2, 3).

Model (1)

When EM was used, the highest mVM stress value was in the restorative crown 107.67 MPa, while the TD value of the EM crown was 0.048 MPa concentrated around the outer inclined planes of the buccal and lingual cusps Fig(4), whereas the highest mVM stress value in the Periodontium 4.43 MPa and the TD value was 0.011 MPa that located at the cervical region of the bifurcation area Fig(5).

For the alveolar bone the mVM values were 8.12 MPa 258.39 MPa for cancellous bone and cortical bone respectively, whiles the TD values were 0.011 MPa 0.014 MPa for cancellous bone and cortical bone respectively Fig(6).

The mVM stress value in the fiber post was 52.56

TABLE (2) Showing the VMs values (MPa) at different areas of crown/root assembly with different restorative crown materials.

	Restorative crown	Periodontium	Cancellous bone	Cortical bone	Fiber post	Remaining tooth structure	Inner canal walls	Composite core
IPS e.max CAD	107.67	4.43	8.12	258.39	52.56	212.81	22.74	29.49
Lava ultimate	38.84	4.43	8.08	260.31	67.16	145.21	22.72	35.98
ZirCAD	141.78	4.44	8.13	257.95	47.09	233.86	22.73	26.75

TABLE (3) Showing the TD (mm) at different areas of of crown/root assembly with different restorative crown materials

	Restorative crown	Periodontium	Cancellous bone	Cortical bone	Fiber post	Remaining tooth structure	Inner canal walls	Composite core
IPS e.max CAD	0.048	0.011	0.011	0.014	0.027	0.035	0.0084	0.034
Lava ultimate	0.062	0.011	0.011	0.014	0.029	0.037	0.0084	0.036
ZirCAD	0.047	0.011	0.011	0.014	0.027	0.034	0.0084	0.033

MPa, while the TD value was 0.027 MPa that was concentrated at the interface of the fiber post with the composite core Fig(7).

In the remaining coronal tooth structure, the mVM stress value was 212.81 MPa, while TD value was 0.035 MPa that located at the upper most buccal area of the preparation Fig(8).

The mVM stress value at the inner dentinal canal walls was 22.74 MPa, while the TD value was 0.0084 MPa Fig(9).

The mVM stress value at the composite core was 29.49 MPa, while the TD value was 0.034 MPa Fig(10).

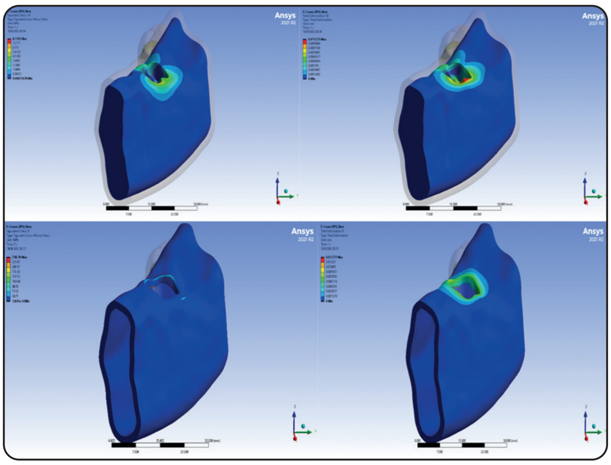

Fig. (6) Stress distribution pattern in alveolar bone in model 1 a) mVM stress values of the cancellous bone, b) TD values in cancellous bone, c) mVM stress values of the cortical bone, d) TD values in cortical bone.

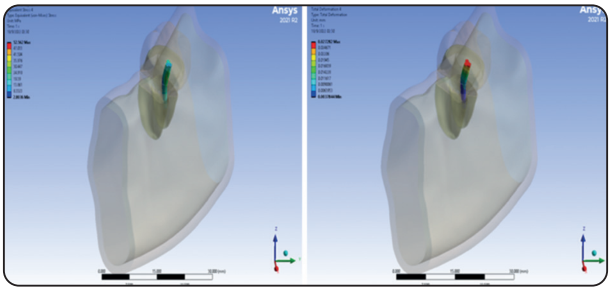

Fig. (7) Model 1 mVM stress values at glass fiber post, b) TD values of the glass fiber post.

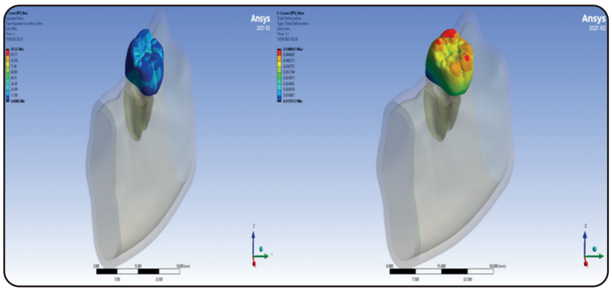

Fig. (4) a) Model 1 mVM stress values in the restorative crown, b) TD values of the EM crown.

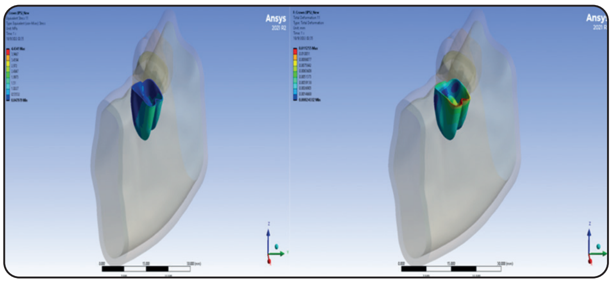

Fig. (5) a) Model 1 mVM stress values at the Periodontium, b) TD values that located at the cervical region of the bifurcation area.

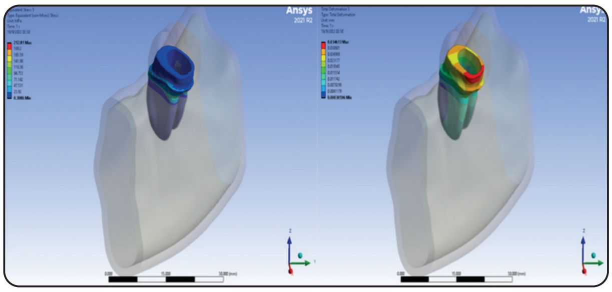

Fig. (8) Model 1 mVM stress values at the remaining tooth structure, b) TD values in the remaing tooth structure.

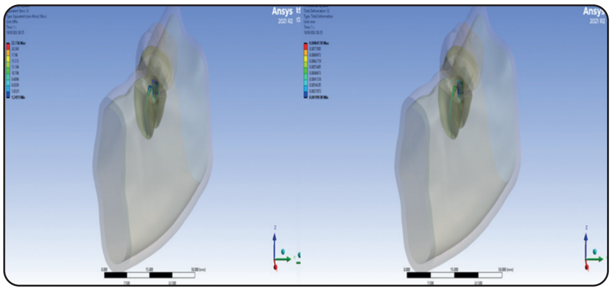

Fig. (9) Model 1 mVM stress values at the inner dentinal canal walls, b) TD values at the inner dentinal canal walls.

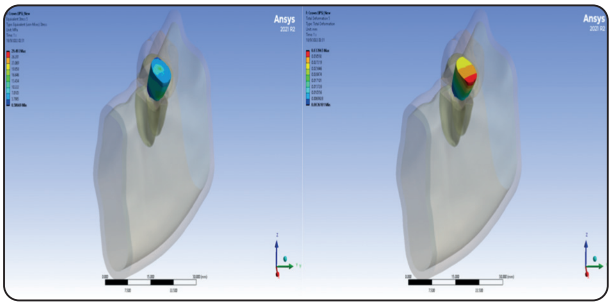

Fig. (10) a)Model 1 mVM stress values at the composite core, b) TD value at the composite core.

Model (2)

When LU was used, the highest mVM stress value was in the restorative crown 38.84 MPa, while the TD value was 0.062 MPa concentrated on the lingual cusps Fig(11), whereas the mVM stress value in the Periodontium was 4.43 MPa and the TD was 0.011MPa that located at the cervical region of bifurcation area Fig(12).

For the alveolar bone the mVM values were 8.08 MPa-260.31 MPa for cancellous bone and cortical bone respectively, while the TD values were 0.011 MPa-0.014 MPa for cancellous bone and cortical bone respectively Fig(13).

The mVM stress values in the fiber post was 67.16 MPa, while the TD was 0.029 MPa that was concentrated at the interface of the fiber post with the composite core Fig(14).

In the remaining coronal tooth structure, the mVM stress value was 145.21 MPa concentrated at the cervical region, while TD value was 0.037 MPa that located at the upper most buccal area of the preparation Fig(15).

The mVM stress value at the inner canal walls was 22.72 MPa, while the TD value was 0.0084 MPa Fig(16).

The mVM stress value at the composite core was 35.98 MPa, while the total TD was 0.036 MPa Fig(17).

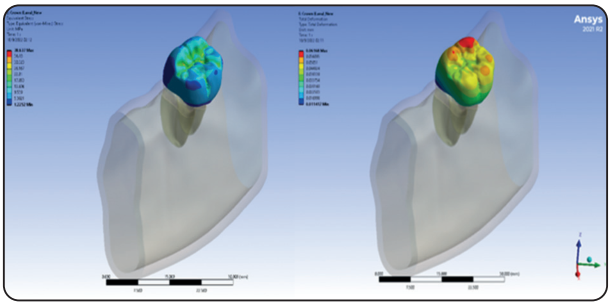

Fig. (11) a) Model 2 mVM stress values in the restorative crown, b) TD values of LU crown.

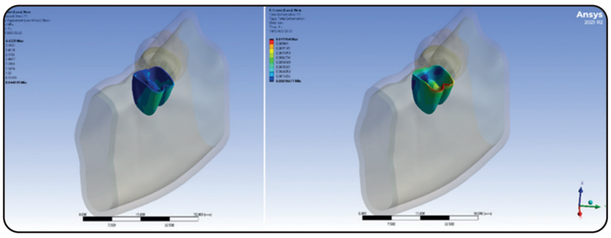

Fig. (12) a) Model 2 mVM stress values at the Periodontium, b) TD values that located at the cervical region of the periodontal bifurcation area.

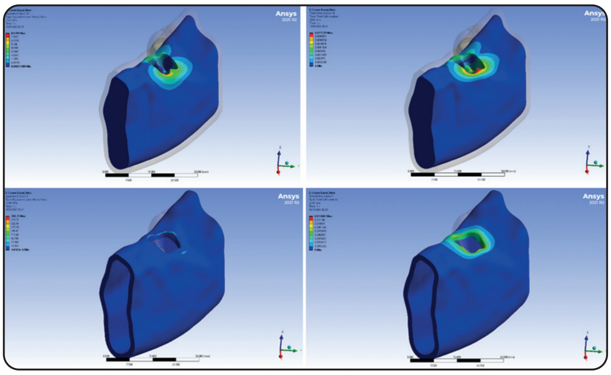

Fig. (13) Stress distribution pattern in alveolar bone in model 2 a) mVM stress values of the cancellous bone, b) TD values in cancellous bone, c) mVM stress values of the cortical bone, d) TD values in cortical bone.

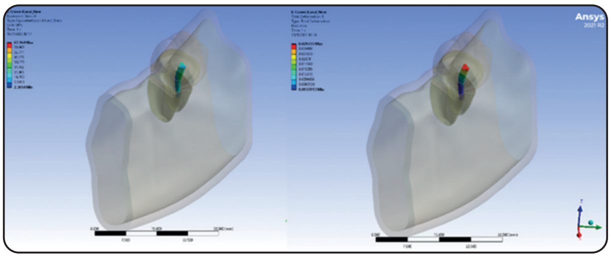

Fig. (14) a) Model 2 mVM stress values at glass fiber post, b) TD values of the glass fiber post.

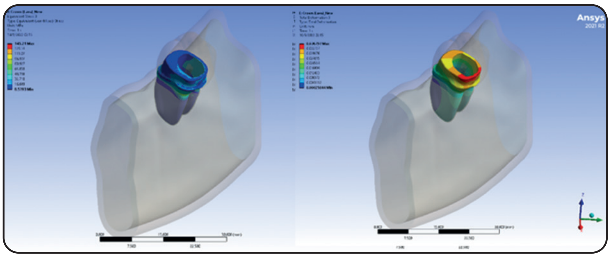

Fig. (15) a) Model 2 mVM stress values at the remaining tooth structure, b) TD values in the remaing tooth structure.

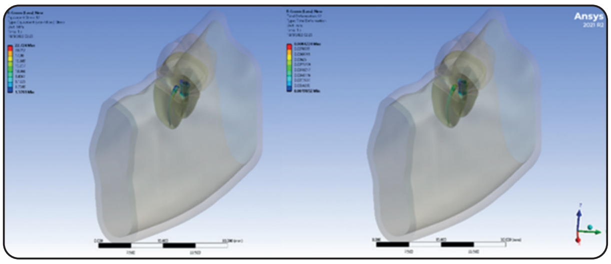

Fig. (16) a) Model 2 mVM stress values at the inner dentinal canal walls, b) TD values at the inner dentinal canal walls.

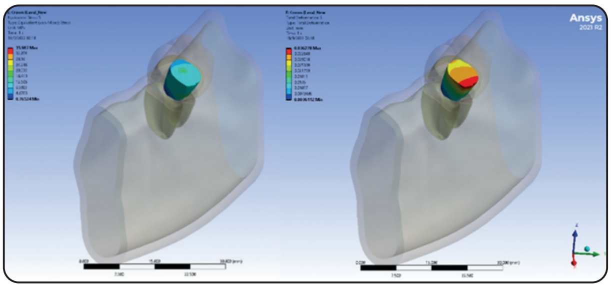

Fig. (17) a) Model 2 mVM stress values at the composite core, b) TD values at the composite core.

Model (3)

When ZC was used, the highest mvM stress value in restorative crown was 141.78 MPa, while the TD value was 0.047 MPa concentrated on buccal and lingual cusps Fig(18), whereas the mVM stress value in the Periodontium was 4.44 MPa and the TD value was 0.011 MPa that located at the cervical region of bifurcation area Fig(19).

For the alveolar bone the mVM values were 8.13 MPa-257.95 MPa for cancellous bone and cortical bone respectively, while the TD values was 0.011 MPa-0.014 MPa for cancellous bone and cortical bone respectively Fig(20).

The mVM stress values in the fiber post was 47.09 MPa, while the TD value was 0.027 MPa that was concentrated at the interface of the fiber post with the composite core Fig(21).

In the remaining coronal tooth structure, the mVM stress value was 233.86 MPa concentrated at the finish line area of the preparation, while TD value was 0.034 MPa that located at the upper most buccal area of the preparation Fig(22).

The mVM stress value at the inner canal walls was 22.73 MPa, while the TD value was 0.0084 MPa Fig(23).

The mVM stress values at the composite core were 26.75 MPa, while the TD was 0.033 MPa Fig(24).

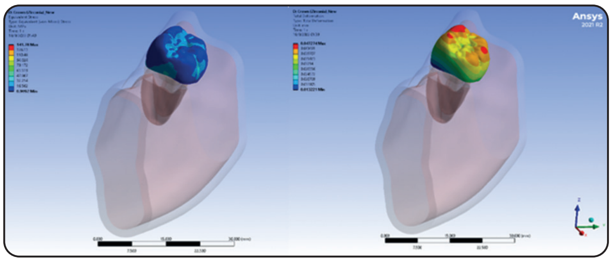

Fig. (18) a) Model 3 mVM stress values in the restorative crown, b) TD values of the ZC crown.

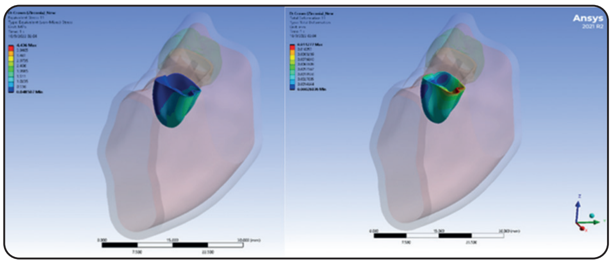

Fig. (19) a) Model 3 mVM stress values at the Periodontium, b) TD values that located at the bifurcation area of the periodontium.

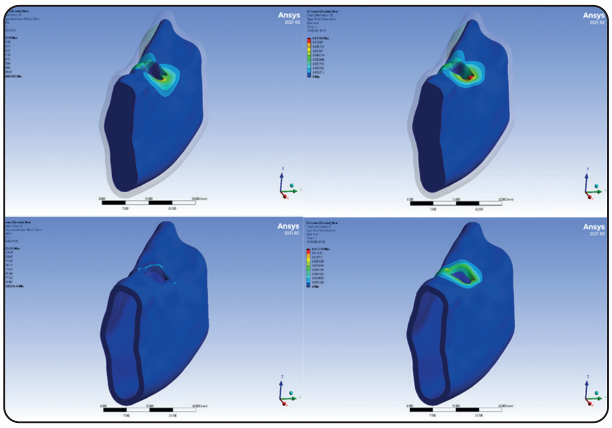

Fig. (20) Stress distribution pattern in alveolar bone in model 3 a) mVM stress values of the cancellous bone, b) TD values in cancellous bone, c) mVM stress values of the cortical bone, d) TD values in cortical bone.

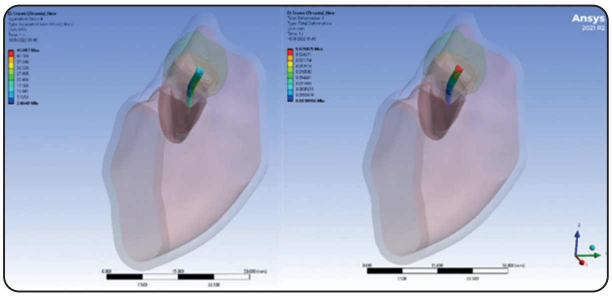

Fig. (21) a) Model 3 mVM stress values at glass fiber post, b) TD values of the glass fiber post.

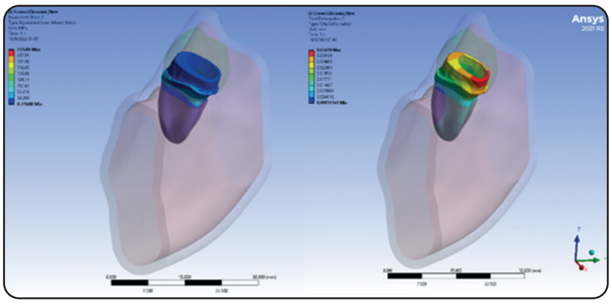

Fig. (22) Model 3 mVM stress values at the remaining tooth structure, b) TD values in the remaing tooth structure.

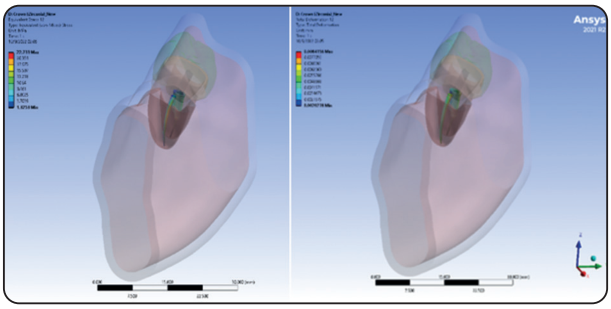

Fig. (23) a) Model 3 mVM stress values at the inner dentinal canal walls, b) TD values at the inner dentinal canal walls.

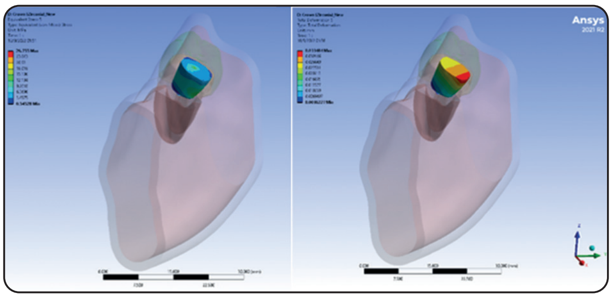

Fig. (24) a)Model 3 mVM stress values at the composite core, b) TD value at the composite core.

DISCUSSION

This in- vitro 3D computerized study simulated the compromised biomechanical condition of endodontically treated mandibular molars. The classical treatment option was a post and core covered by a classical crown constructed from three different restorative materials.

For endodontically treated teeth with partial or complete loss of coronal structure, intracanal retention by post and cores are needed in order to provide retention for prosthetic crowns. Several materials have been offered for intracanal and coronal restoration that must provide adhesion to dentin and core and properly distribute masticatory forces along root long axis.[37]

Previous studies have demonstrated that glass fiber posts associated with composite resin cores are an excellent approach compared to metallic post-and-core and prefabricated metallic posts as a result of excellent clinical performance. They are more esthetic, practical, efficient and less invasive.[38,39] They are presented with good mechanical properties, such as elasticity modulus, similar to dentin which reduces the risk to catastrophic vertical root fracture.[40]

Intra-orally, post and core retained restorations are subjected to masticatory forces. Thus the stress distribution within the structure is multi-axial, non-uniform, and depends on the magnitude and direction of the applied external loads. Thus according to the study by Lanza et al, the ideal materials of post-core systems should be sufficiently elastic to accompany the natural flexural movements of the tooth.[41]

Nondestructive finite element analysis method has been widely used as an excellent tool for analysis of internal structural performance in order to predict long-term failures in every specific region of the crown, tooth, fiber post and surrounding tissues. The FEA allows numerically simulating the behavior of several materials, techniques and designs about displacement and stressing distribution under specific loading.[42,43]

In the present study CBCT was used in order to construct a 3D model thus it is undeniable that the 2D model has its limitations. It can only reflect a simplified plane that has not reflected the 3D structure of teeth, which is not complete in mechanics.

The focus of this study was stress distribution and deformation in different parts of the crown/root assembly, so it needs a clear and definite conclusion of the vertical and oblique components of forces analysis on the molar with two roots. Posterior teeth are subjected to various directions and quantities of both functional and para-functional loads. The highest masticatory load in the posterior region for normal adults is 580 N according to Tortopidis et al.[44] In another study Bakke et al reported that the average magnitude of highest masticatory load varies among females (441 N) and males (522 N).[45]

In the present study, the applied axial load was 600 N (maximum masticatory force) in a vertical and oblique components as much as simulating maximum complex masticatory load.[28, 46]

Compared with the incisor and canine, the force on the molar is relatively vertical, and many molar related studies use vertical force. If there is lateral non axial force, it should also be in bucco-lingual direction.[47, 48]

In order to assess the influence of restorative crown material on endodontically treated teeth, the magnitudes of stresses (mVM) under functional loading conditions were examined among the core, post and dentin, periodontium and surrounding alveolar bone with the use of different crown restorative materials at the analyzed models.

The effect of the periodontal ligament and alveolar tissues, which affected by the transmitted occlusal force, was considered in this study so decrease the limitations of the laboratory conditions.

Under the analytical processing of this study, the results were largely dependent on the Young's modulus and Poisson ratio of the materials and so these data should be considered for each study material.

Although several materials can be indicated for prosthetic restoration of endodontically treated teeth, there is little information about the biomechanical performance of different prosthetic crown restoration for resistance to fracture and compression, success and survival. The present study analyzed the null hypothesis that no significant difference would be found in stress distribution in different parts of the simulated lower endotreated molar or there is no significant difference in stress distribution in the three models that restored with three different crown restorative materials.

Regarding the stress distribution results in model (1) where EM was used and model (3) where ZC was used; the greater mVM stress values were concentrated at the remaining coronal tooth structure, followed the restorative crown, then the fiber post, composite core and inner canal walls and the least VMs values were at root dentin.

Regarding the stress distribution profile in model (2) where LU was used; the greater mVM stress values were concentrated at the remaining coronal tooth structure, followed by the fiber post, then restorative crown, composite core and inner canal walls and root dentin.

So the first part of null hypothesis was rejected since there was difference in stress distribution and values between the different components of the same simulated model.

In the present study, the mVM stresses values were induced at the outer labial region of the root cervical area in all three models. Studies have suggested that high stresses generated on the facial aspect of the coronal third of the root indicated that there was an increased chance of failure of the post and core interface therefore every effort should be made to reduce the stress in the coronal third of the root.[49,50]

In comparing the stress distribution for the digitized three model, the results were: in model (2) with the LU, showed lower stress distribution profile and superior mechanical response along the restorative crown (38.83 GPa) and the remaining coronal tooth structure (145.21 GPa) and in the composite core (35.98GPa) and along the fiber post (67.164GPa) than its corresponding locations when using higher elastic modulus ZC and EM crown restorative material. In EM and ZC models, the stress distribution profiles were generally high this may be attributed to the similar elasticity modulus of LU material and the surrounding structures, reasonable brittleness index and low hardness that grants LU the lower contact stresses and good stress redistribution ability when used as a dental restoration.[15,16,17]

Santos-Filho et al stated that there should be a similarity between the mechanical properties of the restorative material and dental tissues to allow better stress distribution.[40]

As previously stated, LU which is a resin Nano Ceramic is the direct result of ideal nanotechnology that is coupled with resin technology to achieve a combination of strength and esthetic beyond what current e.max ceramics or zirconia blocks can offer.[51]

The influence of adhesion at the interface between different materials on the distribution of stresses should be considered, thus bonding between the resin cement and LU restorations is much better than that to ZC.[52]This is related to the similarity in the mechanical properties of both the resin cement and the LU which might have resulted in better stress distribution along the interfaces. Thus, further study is needed to compare the influence of resin cement chemical nature and bonding mechanism and the stress distribution.

In the present study for the ZC, it was found direct relation between the highest elasticity modulus, transferring the load with higher intensity to the surrounding structures. Therefore, a part of the second null hypothesis was rejected. This result was in agreement with Moris et al who stated that highest elasticity modulus material, absorbing the greatest amount of stress in the whole system. In clinical scenario, it can be predicted that the highest VMs values in those structures would increase the risk to mechanical failure.[21]

As concluded by Veríssimo et al; when body or structure is subjected to load, the stresses will concentrate on the structure with a higher elastic modulus, transferring the load with more intensity to the adjacent structures.[53]

Almost there was similarity in the values of stress distribution profile for the supporting alveolar bone and the remaining inner walls of root dentin and in the periodontium in the models despite great variations in crown material properties, these results showed that the lower elastic modulus of the fiber post and composite core material favored in the stress distribution profile at the interface region of dentin to cemented post. These results were similar to Sun Lee et al that emphasized the importance of the stress distribution at the interface of dentin and the post.[46,54] So the second part of the null hypothesis was partially accepted.

Concerning the deformation that could occur in the 3 models; the study demonstrated that when Young's modulus approaching that of dentin a more desirable decrease in stresses transmitted to the remaining tooth structure and the root, thus reducing the risk of root fracture. The ideal root canal post must be sufficiently elastic to accompany the natural flexural movements of the structure of the tooth [55], also the restorative crown material with low elasticity modulus as LU offer less maximum deformation on the crown restorative material, remaining tooth structure and on the post and assumed as a monoblock system that provided uniform stress distribution than the material with high elasticity modulus as ZC.

The results was in agreement with Gomes et al who illustrated that the maximum deformation pattern on the root surface of the tooth, periodontal ligament and alveolar bone were nearly the same when restoring with different protocols .[56]

This result is similar to the previous study of Sorrentino et al, which conducted an FEA with a tooth model composed of a post, core, and crown, and it revealed that the crown component protects the whole system in the entire post-core restored tooth model so stresses is normally distributed.[57]

In the present study, only the restorative crown in model 2 where LU crown restorative material was used the MD (0.062mm/s) was much more than for the EM (0.049mm/s) and the ZC (0.047mm/s). So the lower elasticity modulus of the material render it to become more susceptible to deformation although better distribution of stresses in the crown/root and alveolar tissues assembly. That may suggest that the LU restoration may tend to develop retrievable failure and protect the tooth tissue and a favorable prognosis. [58]

The results were in agreement with Meng et al; [28] they stated that; the elastic modulus of the LU restoration was significantly lower than the EM restorations, and the low elastic modulus of the materials absorb more stresses and reduce the stress distribution of tooth tissue, which is consistent with the Yamanel et al.[59]

As postulated by Magne, et al a lower flexural modulus correlates to increased deformation under load, suggesting that Lava Ultimate restorative is more likely to absorb the stress than glass-ceramics. In addition, the combination of high strength with low modulus translates to greater resilience.[60]

The modulus of resilience of Lava Ultimate restorative is statistically significantly higher IPS e.ma CAD. This means that Lava Ultimate restorative can absorb significantly more stress than these materials without suffering permanent deformation or failure.[61]

All information in the present study was illustrating the influence of crown restorative material on the mechanical behavior of endodontically treated tooth with post and core using FEA. However, in reality there will be other factors that consider limitation of this present study, it is impossible for a computer simulation to include the factors in oral environment. Since all structures were assumed as isotropic, homogeneous, linearly elastic, while the properties of tooth structures are not isotropic and homogeneous due to capillary morphology of dentin and prismatic structure of enamel so, liability for micro-crack at the interface, damage for the hard tissues and the restorative materials may occur. Computer simulation cannot reproduce the dehydration and loss of collagen after endodontic treatment; which affects the resistance to tooth fracture. Therefore, further laboratory and clinical studies, including aging effects, are required to verify and supplement the present study.[62]

CONCLUSION

1. Post/core material with similar biomechanical properties to dentin could be advantageous in reducing the risk of root fractures.
2. The stress concentration at endodontically treated molars restored with post and core could be lowered by the use of crown restorative material has low elastic modulus as the resin nano ceramic material.
3. The highest values of VMs were recorded at the remaining tooth structure, and at the restorative crown materials with different types of crown restorative material.
4. Although high values of VMs were more detected at the ZC crown restorative material that not predicts its failure.

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