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# THREE DIMENSIONAL FINITE ELEMENT ANALYSIS OF THE EFFECT OF CAVITY DESIGN PREPARATION AND 3D PRINTED RESIN COMPOSITE RESTORATIONS ON STRESS DISTRIBUTION IN ENDODONTICALLY TREATED MOLARS

Rehab Khalil Safy* *and* Mai Hamdy Ragab**

*ABSTRACT*

**Purpose:** Analysis of the stress distribution in endodontically treated molars with different cavity designs that have been restored with 3D printed resin composite restorations under occlusal load using 3D finite element analysis (FEA)**.**

**Methods:** A 3D model of untreated intact maxillary first molar was created to act as a positive control group. Root canal treatment simulation was performed in six models that were designed for the same maxillary first molar studied, and then they divided into three groups taking into account the prepared cavity design (n=2); inlay, onlay and endocrown. The created six models received standardized MOD inlay cavity design. Reduction of both functional and non-functional cusps was performed with a 90-degree butt joint margin for preparation of onlay and endocrown models. Then, each simulated cavity design was divided into two sub groups according to the utilized restorative material (n=1); 3D printed and CAD/CAM resin composites. Vertical Force was applied, and then Von Mises (VM) stress values were evaluated at enamel, dentin, cement interface and tested restorative material of each model using the FEA.

**Results:** Endocrown cavity design showed the best distribution of stresses in the remaining tooth structure of endodontically treated teeth. CAD/CAM resin composite restorations absorbed higher VM stress values in comparison to models restored with 3D printed resin composite in each tested cavity design.

**Conclusion:** CAD/CAM resin composite endocrown has been determined to be the most effective option for endodontically treated molar restoration among the examined restorations based on the distribution of stress in the remaining tooth structure and the cement interface.

**KEYWORDS:** 3D printed resin composite, CAD/CAM, Inlay, Onlay, Endocrown, 3D FEA.

* Assoc. Prof of Conservative Dentistry, Faculty of Dentistry, Suez Canal University,
** Assoc. Prof of Endodontics, Faculty of Dentistry, Suez Canal University

## INTRODUCTION

The clinical challenge of endodontically treated teeth (ETT) rehabilitation arises from the increased risk of teeth fracture resulting from poor structural integrity imposed by caries and/or iatrogenic effect.[1] Determining the optimal restorative approach for each case requires considering into account the amount and quality of the remaining tooth structure, as invasive restorations lead to its weakening.[2, 3] The decision of how to restore endodontically treated molars is challenging and has always been a controversial subject. The optimum restoration for their reconstruction has not yet been unanimously decided.[4] The durability of restored ETT is significantly affected by the cavity design and the utilized restorative material.[5] Actually, minimally invasive procedures that preserve as much tissue as possible are regarded as "the gold standard" for their restoration.[6, 7] In such case, it is critical to select an appropriate restorative material that maintains integrity of the restored tooth.[8]

Conservative restorations emerged as a consequence of developments in adhesive dentistry and emphasized the use of minimally invasive designs that could extend the restoration's durability.[9,10] According to this deductive thinking, conservative restorations like inlays and onlays can be planned in place of full coverage restorations when sufficient amount of remaining tooth structure is available in the ETT.[11] In order to restore posterior teeth with extensive coronal damage, endocrown restorations have been proposed as a more practical option than post and core retained ones.[12] When compared to traditional crowns, endocrown is easier in preparation and require less clinical time.[13–15] Molars treated with endocrowns may be less likely to fracture than those restored with posts, according to certain theories.[16] Furthermore, it considered as a suitable option to restore teeth with insufficient ferrule effect,[17] inadequate inter-occlusal space,[18] short, broad, and dilacerated root canals.[19] Moreover, it is easier to perform re-interventions in case of endodontic failure.[20]

It has been reported that in addition to tooth preparation design, ETT restoration performance is restorative material dependent.[21] Based on having a comparable elastic modulus to dentin, with proper stress distribution, resin composite is one of the materials of choice for restoration of the ETT particularly in patients who exhibit high masticatory forces and parafunctional habits.[22, 23] Consequently, resin composite inlays, onlays, and endocrowns have become promising options. Recently, digital dental manufacturing is developing at an astonishing rate. The advent of three-dimensional (3D) printed resin composite materials with enhanced mechanical properties were introduced thanks to availability of 3D printers and post-processing equipment. By layering on tiny pieces of the material, this additive manufacturing 3D printing technology creates the desired restoration. The ability to still influence the mechanical and aesthetic qualities of the restoration to be printed during its manufacturing is one feature that gained popularity which is not the case in CAD/CAM subtractive manufacturing as the material properties of the prefabricated blocks are defined by the manufacturer. As a result of this customizable feature and the fact that digitally created products take less time to manufacture and waste less raw material, additive manufacturing can be an economical option for creating restorations and could be considered as a key component of digital dentistry.[24] Nevertheless, there is a dearth of data and thorough research on 3D printed resin composite materials clinical performance in terms of stress distribution when used to restore ETT.

Recently, 3D FEA has shown a great deal of application in dentistry since it provides a mathematical non-destructive prediction of the mechanical behavior of materials.[25] Aiming to provide a reference for proper selection of the optimal restoration that ensure better stress response and preserve as much tooth structure as possible from the biomechanics perspective, the purpose of the present study was to evaluate the effect of cavity design preparation and 3D printed resin composite restorations in comparison to CAD/CAM ones on stress distribution in endodontically treated maxillary molars using FEA. The first null hypothesis of the current study is that cavity preparation design will not affect the stress distribution in endodontically treated molars; the second null hypothesis is that the 3D printed resin composite restorations are not superior to CAD/CAM ones in terms of stress response to masticatory load.

## MATERIALS AND METHODS

### Designing of finite element models

High resolution cone beam CT (Planmeca Pro Max 3D Mid, Planmeca OY, Finland) was used to scan a sound, recently extracted maxillary first molar extracted for periodontal reasons in endodontic mode to obtain realistic and precise model dimensions. Institutional approval was performed for the study protocol by the Ethical Committee of Suez Canal University (890/2024). The tooth's dimensions and form matched those found in the anatomical atlas.[26] Importing of scans and isolation of dental structures using a software (Materialise Mimics, 21.0, Leuven, Belgium) were carried out. Then, generating of STL files which was optimized using 3-Matic software (version 11.0, Leuven, Belgium) was performed. The optimized STL files were utilized in a software program Solidworks 2020 (Dassault Systèmes, France) to produce the parametric file which was used to complete the required three dimensional models of the untreated intact tooth (Fig. 1).

Following natural tooth simulation, three groups of models were simulated (n=2) based on the prepared cavity design: inlay, onlay, and endocrown. Standardized mesio-occluso-distal (MOD) cavity design preparations were performed for all utilized models following general guidelines for aesthetic inlay restorations (Fig. 2). Buccal and palatal walls thickness of each model was simulated to be 2 mm.[4, 27] All preparations had supragingival margin that was placed at 1 mm, just above the CEJ.[28] From the cavity base to the cavosurface, all prepared cavity walls tapered 10 degrees, and the cavosurface angles were simulated in the form of butt joints (90°), in addition to rounding of all internal line and point angles. Designing of both onlay and endocrown models were achieved as mentioned for inlay design in addition to 2 mm reduction of both functional and non-functional cusps with a 90-degree butt joint margin (Fig. 3).[29-31] After cavity designs simulation, simulated root canal therapy was performed for all prepared models. Preparation of the root canals and Gutta-percha filling were performed to simulate the endodontic treatment as the following; MB1, MB2, DB size 30 and palatal root canal size 40 and all were of 0.04 taper (Fig. 4-6). The pulp chamber of both inlay and onlay models was simulated to be lined with flowable resin composite (G-aenial Universal Flo, GC, America).[29]

Then, each virtual cavity design was represented by two restorative materials: 3D printed resin composite (Crowntec®, SAREMCO Dental AG, Rebstein, Switzerland) and CAD/CAM resin composite blocks (Brilliant Crios®, Coltène, Whaledent AG, Altstätten, Switzerland). A layer of dual-curing resin cement (DuoCem, Coltene, Whaledent) was mimicked between cavity walls and each restoration's fitting surface, measuring 100 µm in thickness. This approach seemed more in line with clinical practice.[32] All models had their roots encircled by a 0.2 mm periodontal ligament and surrounded by bone. All involved materials were assumed to be linearly elastic, isotropic, and homogeneous in order to overcome computational constraints.[33] Then, all models were subjected to linear static FEA using the FEA tool box provided by Solidworks 2020.

### Mesh creation

The system domain is split up into a number of finite elements that depend on the meshed structural geometry in this procedure, which is a necessary step in the FEA to produce predictions on complicated geometries. Thus, a precise representation of the geometry of the real model was provided by the meshing process (Fig. 7). The models were all derived from the same mesh design to avoid variations in the stress levels. For every model, a node-based mesh of linear tetrahedral quadratic elements was created. The minimal number of elements and nodes required for reliable numerical results were determined (Table 1) following the mesh convergence test with a 10% relevance level (Fig. 8).

TABLE (1) Total number of the models' elements and nodes in all meshed components.

| Models | Elements | Nodes |
|---|---|---|
| Intact tooth | 27206 | 43305 |
| Inlay | 48175 | 77761 |
| Onlay | 48924 | 78857 |
| Endocrown | 50523 | 81869 |

### Materials' mechanical properties

Table 2 summarizes the mechanical characteristics of the simulated dental tissue and materials, including Young's modulus (Elastic modulus) and Poisson's ratio based on the manufacturers and the literature. Young's modulus measures the stiffness of an elastic material, whereas Poisson's ratio measures the ratio of axial strain in the direction of the given stress to transverse strain perpendicular to the applied load.[34] All interfaces, were considered to be entirely bonded.[20]

TABLE (2) The mechanical characteristics of simulated materials.

| Tooth structure/ Materials | Young's Modulus (GPa) | Poisson's ratio | References |
|---|---|---|---|
| Enamel | 84.1 | 0.33 | 33 |
| Dentin | 18.6 | 0.32 | 35 |
| Periodontal ligament | 0.15 | 0.45 | 33 |
| Cortical bone/ Cancellous bone | 13.7 & 1.37 | 0.30 | 35 |
| Gutta-percha | 0.14 | 0.45 | 36 |
| CAD/CAM resin Composite blocks Brilliant Crios (Coltène, Whaledent AG, Altstätten, Switzerland) | 10.3 | 0.30 | 32 |
| Crowntec resin composite (SAREMCO Dental AG, Rebstein, Switzerland) | 4 | 0.35 | 37 |
| DuoCem (Coltene/Whaledent) | 6.5 | 0.33 | 32 |
| G-aenial Universal Flo (GC, America) | 7.9 | 0.3 | 38 |

**** Gpa: Gega pascal.***

### Boundary condition, model fixation and load application

A crucial component of FEA is the boundary condition, which represents the pattern of movements originating at the nodes and their connections. In order to restrict movement in the three axes, FEA models were thought to be securely fixed at the nodes in mesial and distal areas of the bone by confining all degrees of freedom.[39] To simulate a normal vertical mastication load, a constant 250 N vertical occlusal force was applied to the models' central groove.[40] Following the establishment of the loading angle, boundary conditions, element arrangement, and mechanical properties of the materials, the analysis of failure prediction potential was used to determine the appropriate stress representation measure. Using the FEA software program Solidworks 2020 the equivalent VM stress distribution clouds were expressed in Mega Pascals (MPa). In all models, the FEA results were displayed as maps using a linear color scale that ranges from the lowest values (blue) to the highest values (red). The von Mises theory was utilized to evaluate the stress distribution in enamel, dentin, cement layer and restorative materials for all tested cavity designs. Moreover, the Solidworks 2020 software program was utilized for calculation of the volume of remaining tooth structure for each tested cavity design.

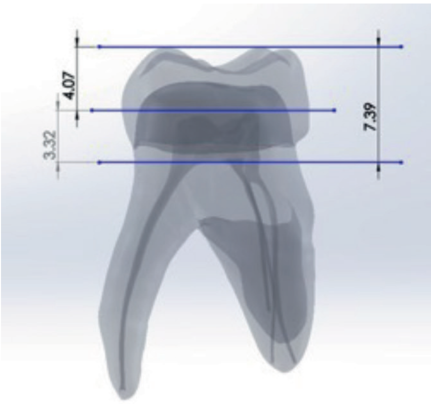


Fig. (1) Simulated natural intact maxillary first molar.

Fig. (2) Simulated inlay cavity design.

Fig. (3) Simulated onlay & endocrown cavity designs.

Fig. (4) Distal view of simulated endodontically treated maxillary first molar restored with inlay.

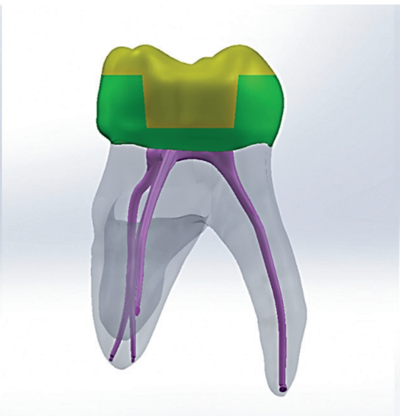

Fig. (5) Distal view of simulated endodontically treated maxillary first molar restored with onlay.

Fig. (6) Distal view of simulated endodontically treated maxillary first molar restored with endocrown.

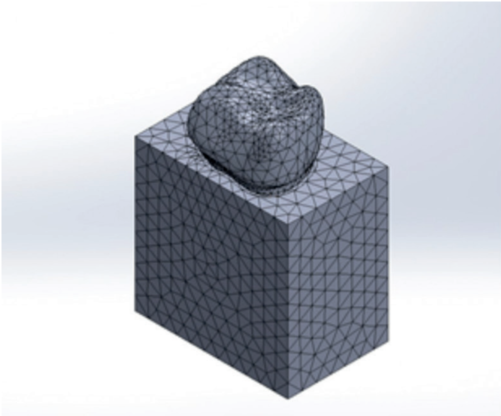

Fig. (7) Mesh formation of the simulated model.

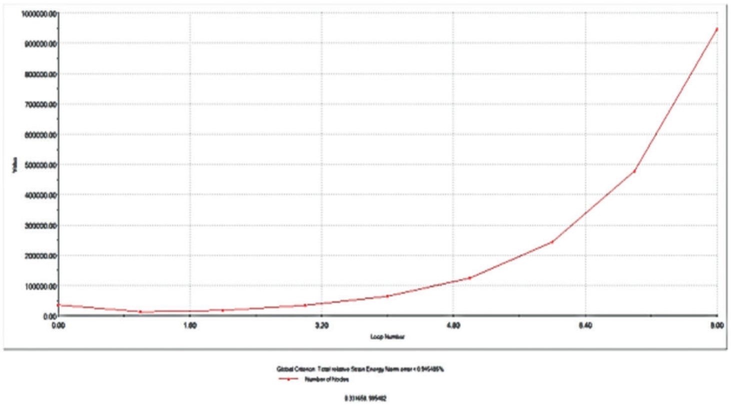

Fig. (8) Convergence graph showing the total number of nodes.

## RESULT

The maximum stress values evaluated in MPa are summarized in Table (3).

TABLE (3) Maximum von Mises stress (MPa) in dental structures and restorative materials in all models

| | Enamel | Dentin | Cement layer | Restorative material |
|---|---|---|---|---|
| 3D resin composite inlay | 24.451 | 208.368 | 10.208 | 345.235 |
| CAD/CAM resin composite inlay | 23.402 | 170.467 | 9.035 | 357.955 |
| 3D resin composite onlay | 27.937 | 115.791 | 9.420 | 279.169 |
| CAD/CAM resin composite onlay | 25.261 | 84.698 | 8.142 | 294.100 |
| 3D resin composite endocrown | 20.989 | 27.653 | 5.867 | 226.559 |
| CAD/CAM resin composite endocrown | 15.536 | 29.205 | 3.691 | 239.257 |

### Volume of remaining tooth structure

Calculation of the volume of residual dental tissues of all evaluated cavity designs revealed that inlay cavity design represented the highest volume (860.17 $mm^3$) followed by onlay (826.86 $mm^3$) while, the least amount of remaining tooth structure was recorded in the endocrown cavity design (770.41 $mm^3$).

### Stress distributions in enamel

According to stress distribution clouds, the color maps showed that intact tooth model showed VM stress accumulation at the point of application of the vertical load with proper distribution of stresses on the remaining enamel surface (Fig. 9). The color maps of all restored models reveled that vast amount of stresses (hot areas) were represented in the gingival margins and internal palatal enamel wall of inlay cavity design (Fig. 10 & 11) followed by the onlay (Fig. 12 & 13) meanwhile the least amount of hot areas and least VM stress value were represented in the endocrown cavity design (Fig. 14 & 15). It worth noting that, although the value of maximum VM stress found in enamel of inlay cavity

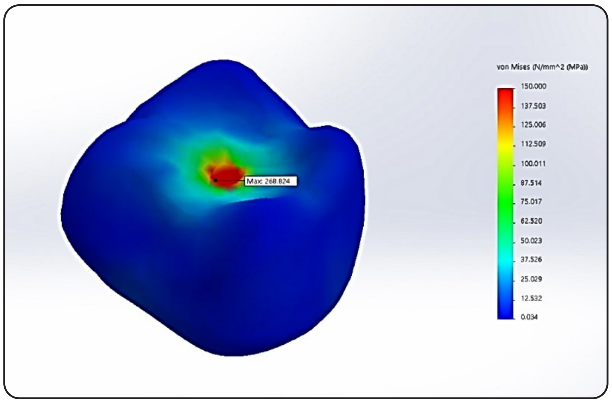


Fig. (9) Stress Distribution in intact tooth enamel design showed a comparable value to that found in onlay, the distribution of stresses according to the color maps showed better distribution of stresses in the occlusal aspect of the reduced cusps present in onlay cavity designs. Additionally, evaluating the distribution of stresses in restored models demonstrated that the least amount of VM stresses were found in enamel of CAD/CAM models in comparison to the enamel of models restored with the 3D printed resin composite restorations.

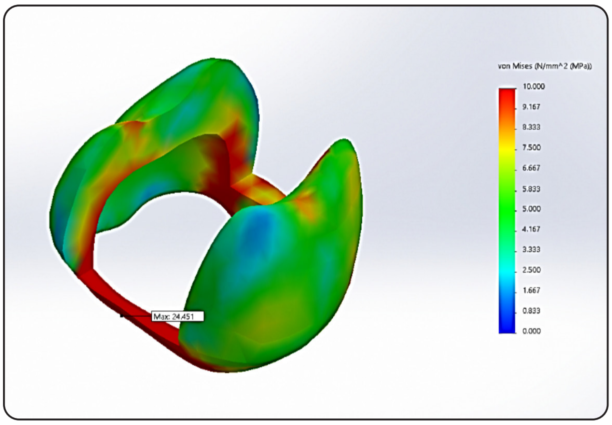


Fig. (10) Stress distribution in enamel of inlay model restored with 3D printed resin composite.

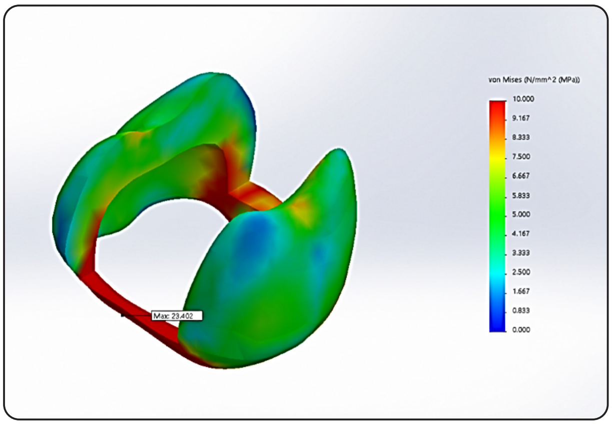


Fig. (11) Stress distribution in enamel of inlay model restored with CAD/CAM resin composite.

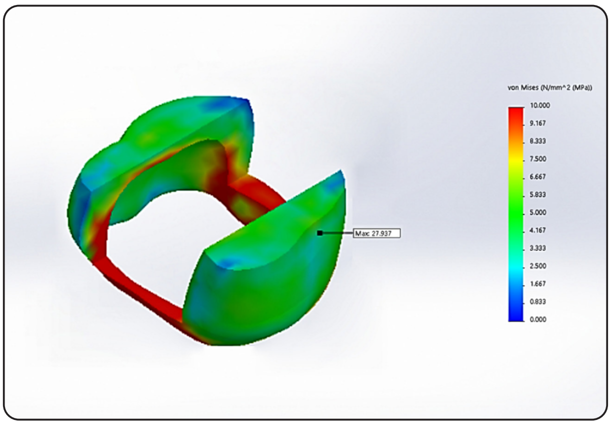


Fig. (12)Stress distribution in enamel of onlay model restored with 3D printed resin composite.

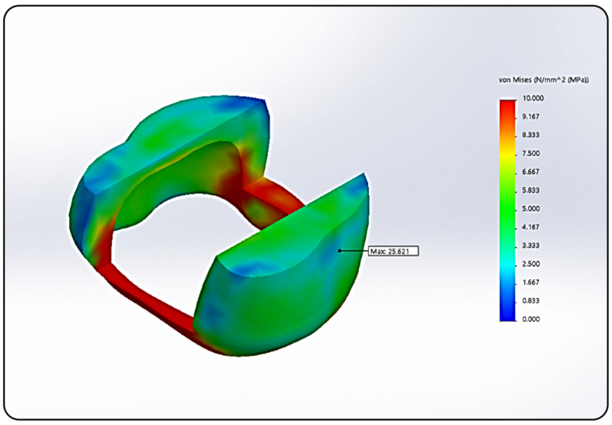


Fig. (13) Stress distribution in enamel of onlay model restored with CAD/CAM resin composite.

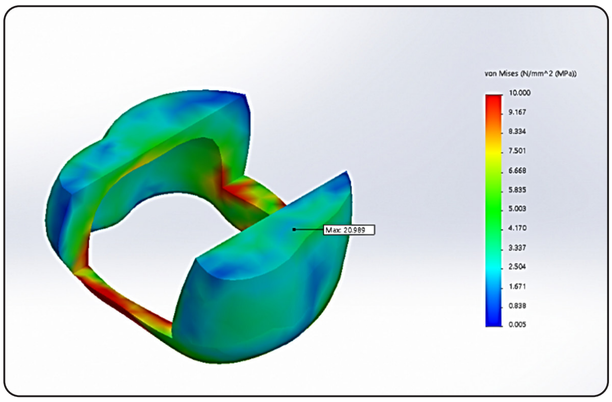


Fig. (14) Stress distribution in enamel of endocrown model restored with 3D printed resin composite.

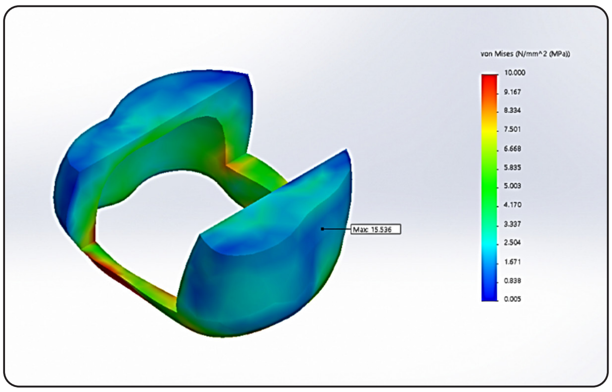


Fig. (15) Stress distribution in enamel of endocrown model restored with CAD/CAM resin composite.

### Stress distribution in dentin

Regarding to stress distribution clouds in dentin, the results revealed that all tested models showed VM stress at the point of application of the vertical load with proper distribution of stresses on the remaining dentin surface in intact tooth model (Fig. 16). Considering the effect of cavity design on distribution of stresses, the results of the color maps of dentin of different tested models showed that highest VM stress values were recorded in inlay (Fig. 17 & 18) followed by onlay (Fig. 19 & 20) meanwhile, the lowest values were recorded in endocrown model for both tested restorative materials (Fig. 21 & 22). Notably, models restored with 3 D printed resin composite had more stress concentration with higher VM stress values in dentin in comparison to CAD/CAM models in all cavity designs. More concentration of hot spots were observed at the base of palatal cusps and cervical area of both inlay and onlay cavity designs with more predominance in the inlay models of 3D printed models. In contrary, endocrown models revealed better distribution of the stresses in such areas. Although, the highest VM stress value recorded by dentin found in inlay cavity deign restored with 3D printed resin composite model (208.368 MPa), the lowest VM stress values were found in dentin of both endocrown models which were restored with either 3D printed or CAD/CAM resin composite with nearly similar values (27.653, 29.205 MPa) respectively.

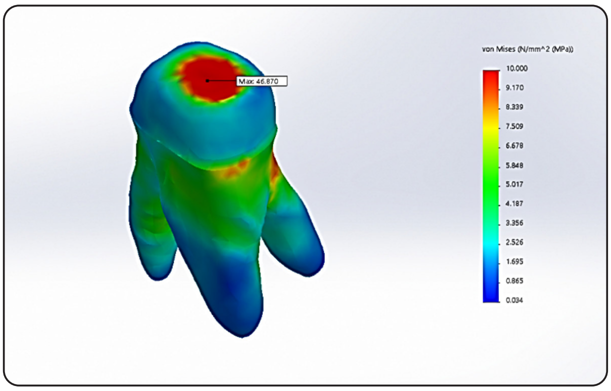


Fig. (16) Stress distribution in intact tooth dentin.

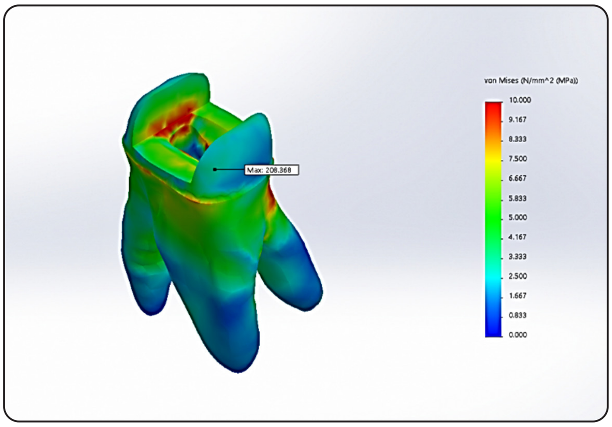


Fig. (17) Stress distribution in dentin of inlay model restored with 3D printed resin composite.

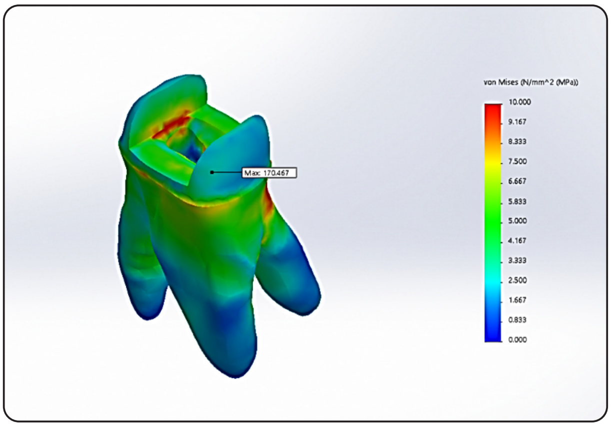


Fig. (18) Stress Distribution in dentin of inlay model restored with CAD/CAM resin composite.

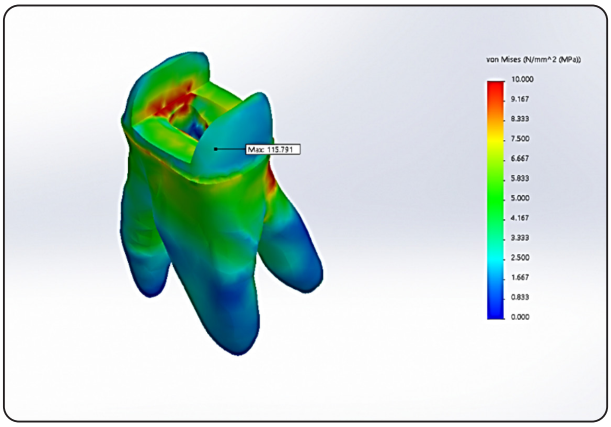


Fig. (19) Stress distribution in dentin of onlay model restored with 3D printed resin composite.

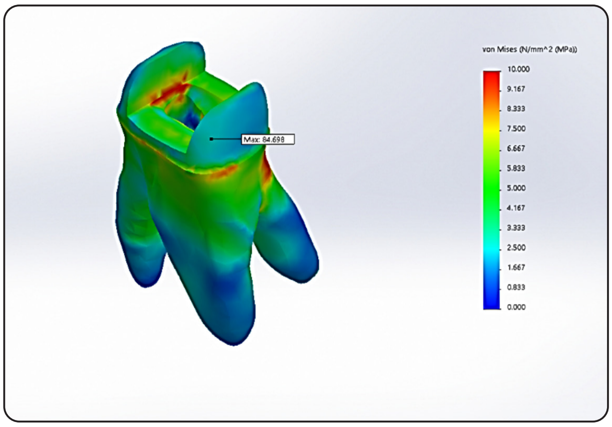


Fig. (20) Stress distribution in dentin of onlay model restored with CAD/CAM resin composite.

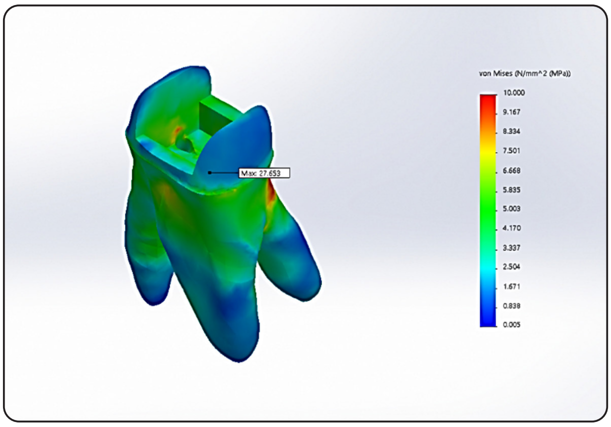


Fig. (21) Stress distribution in dentin of endocrown model restored with 3D printed resin composite.

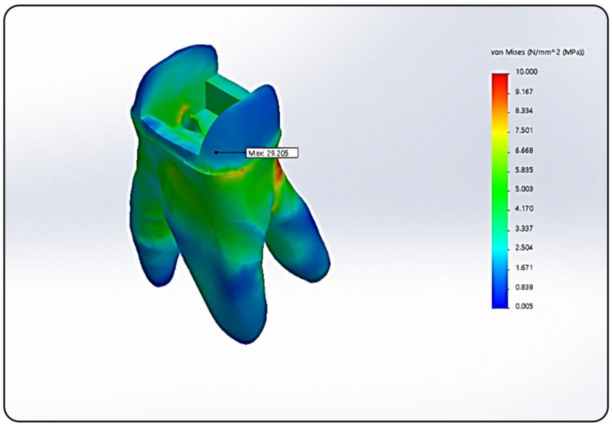


Fig. (22) Stress distribution in dentin of endocrown model restored with CAD/CAM resin composite.

### Stress distribution in restorative materials

The color clouds showed that stresses were concentrated in the area where the vertical load was applied in the occlusal surface of all tested models. However, much better distribution of stresses through both coronal and radicular areas without any stress concentration at cervical area was observed in intact tooth model in comparison to restored ones (Fig. 23). On the other side, evaluating the stress distribution through both coronal and radicular areas in different tested cavity designs revealed that the highest amount of hot spots was observed in inlay cavity design (Fig. 24 & 25) followed by onlay (Fig. 26 & 27) meanwhile, the best distribution of stresses was recorded in endocrown cavity design (Fig. 28, 29). Also, both inlay and onlay cavity designs complaining from concentration of stresses at the cervical area which was more prominent in inlay in comparison to onlay cavity design. When the stress distribution in both tested restorative materials was evaluated, the results showed that all CAD/CAM resin composite restorations absorbed higher VM stress values in comparison to models restored with 3D printed resin composite in each tested cavity design with much better distribution of the stresses to its surrounding tooth structure.

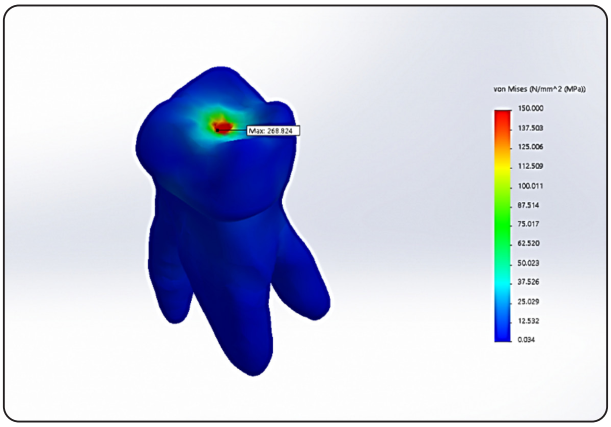


Fig. (23) Stress distribution in intact tooth.

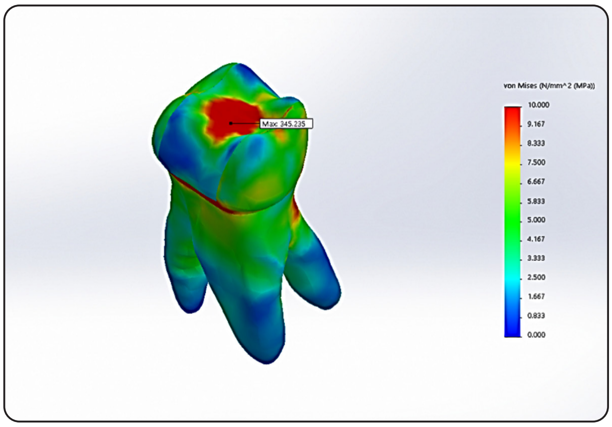


Fig. (24) Stress distribution in molar model restored with 3D printed resin composite inlay.

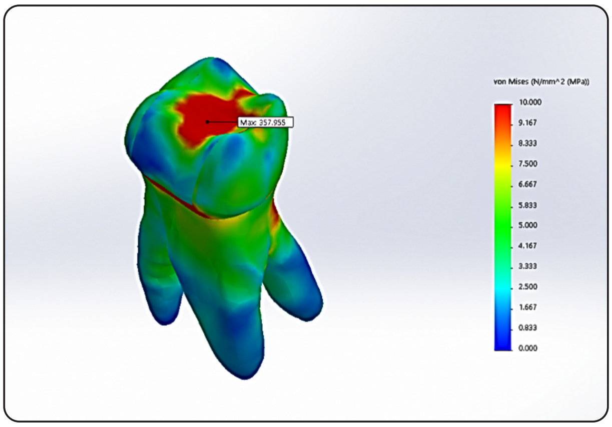


Fig. (25) Stress distribution in molar model restored with CAD/CAM resin composite inlay

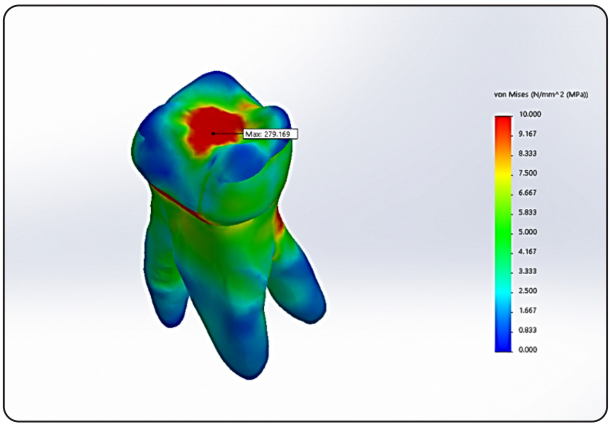


Fig. (26) Stress distribution in molar model restored with 3D printed resin composite onlay.

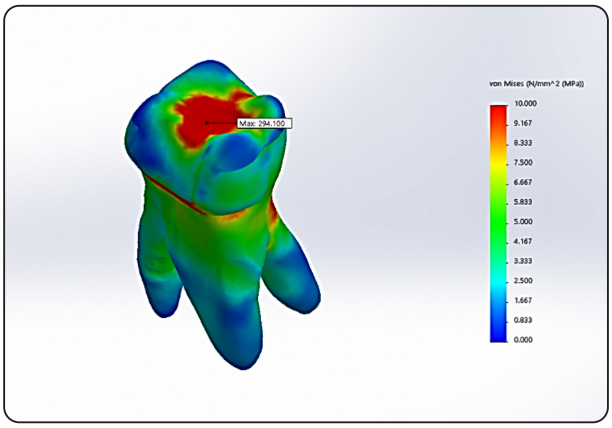


Fig. (27) Stress distribution in molar model restored with CAD/CAM resin composite onlay

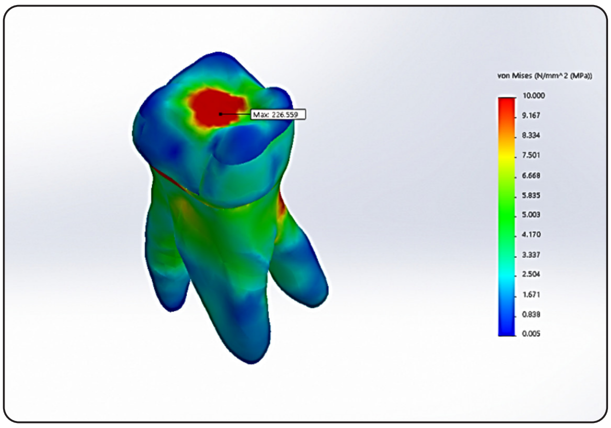


Fig. (28) Stress distribution in molar model restored with 3D printed resin composite endocrown.

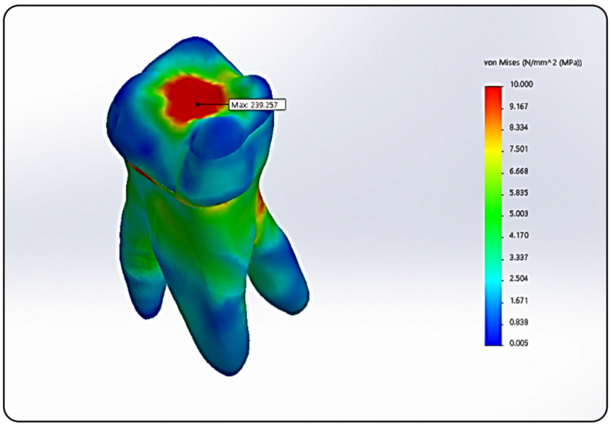


Fig. (29) Stress distribution in molar model restored with CAD/CAM resin composite endocrown

**Stress distribution in cement layer**

Regarding the distribution of stresses in cement layer of all restored models, it was observed that both inlay (Fig. 30, 31) and onlay restorations (Fig. 32, 33) showed the highest stress transfer to the cement interface meanwhile, the endocrown models transmitted the lowest stress values to this area at both tested restorative materials (Fig. 34, 35). Examining the impact of restorative material type on the VM stress values showed that models restored with CAD/CAM showed less stress transfer to the bonded interface than models restored with 3D printed resin composite.

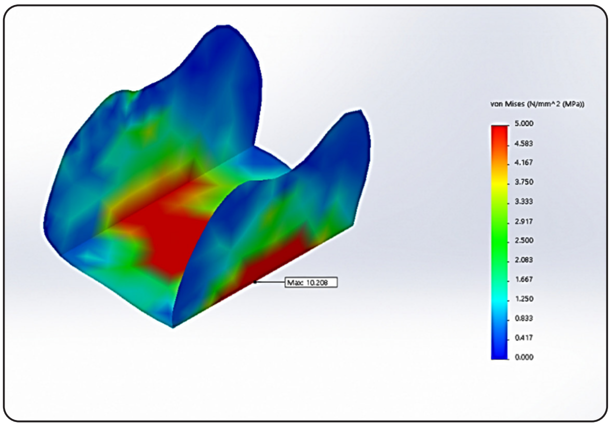


Fig. (30) Stress distribution in cement layer of inlay model restored with 3D printed resin composite.

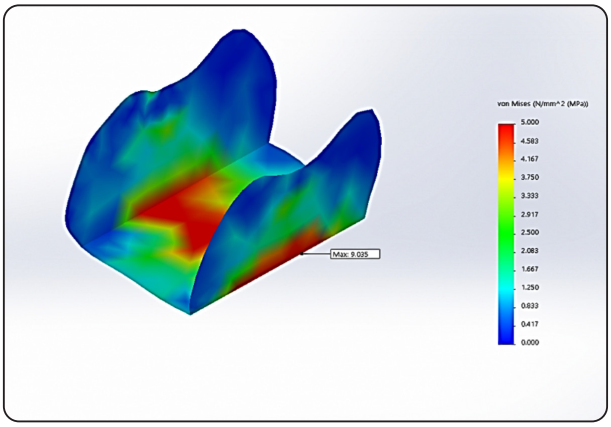


Fig. (31) Stress distribution in cement layer of inlay model restored with CAD/CAM resin composite.

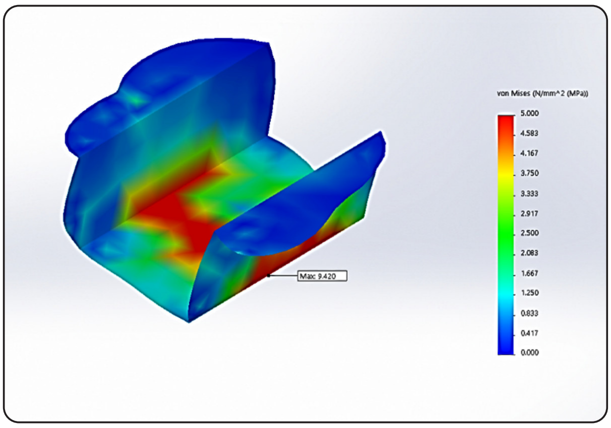


Fig. (32) Stress distribution in cement layer of onlay model restored with 3D printed resin composite.

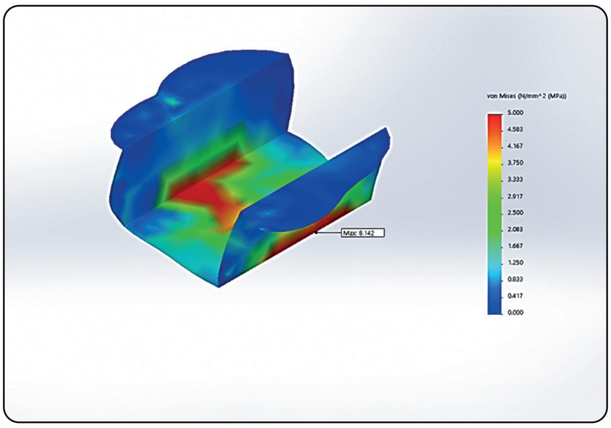


Fig. (33) Stress distribution in cement layer of onlay model restored with CAD/CAM resin composite.

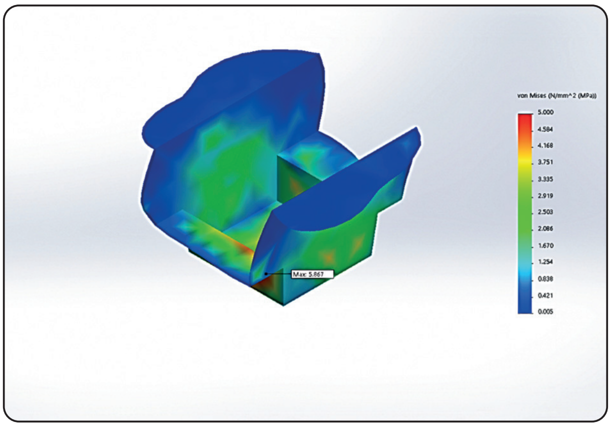


Fig. (34) Stress distribution in cement layer of endocrown model restored with 3D printed resin composite.

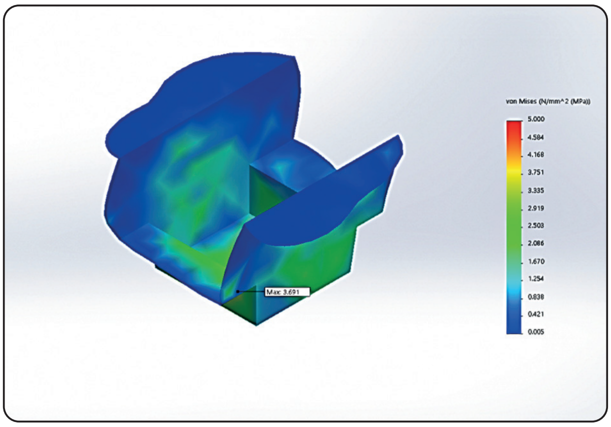


Fig. (35) Stress distribution in cement layer of endocrown model restored with CAD/CAM resin composite.

## DISCUSSION

Selecting a restorative material for teeth with endodontic treatment requires careful planning, which may pose a problem for the restorative dentist. There is ongoing debate surrounding clinical data about non vital teeth restoration, which sometimes depends on conflicting empirical studies. It has always been a challenge to determine the best conservative preparation and the optimal restorative material to minimize the deteriorating influence of applied stresses on such teeth following endodontic treatment.[41, 42] However direct restorative treatments had always been suggested as an available option with the advantages of reduced cost and less chair side time, it demonstrated lower fracture resistance and questionable durability in such condition when compared to indirect ones.[43] Thanks to recent developments in adhesive dentistry have made minimally invasive restorations a viable substitute for full-coverage crowns, provided that there are enough tooth structure available for bonding.[44] Consequently, using bonded ceramic inlays, onlays, and endocrown to restore ETT with coronal damage became practical. Nevertheless, there are still concerns regarding the clinical durability of such minimally invasive restorations.[45] Till now, solving the mystery of the fracture resistance of ETT reconstructed with inlays, onlays, and endocrowns is enigmatic.

Although ceramics have long been used to fabricate indirect CAD/CAM restorations because of their excellent mechanical and aesthetic qualities, they are brittle materials that are highly prone to failure when defects are present. In an effort to provide a more realistic stress distribution, multiple studies have recently advocated for the use of materials for indirect bonded restorations that have an elastic modulus comparable to dentin. This approach involves the introduction of a recently developed subtractively manufactured CAD/CAM resin composite with lower elastic modulus and hardness values than glass-ceramics,[46] which makes them easier to mill and adjust intraorally. They are also less prone to chipping and fracture, and they wear down opposing teeth less.[47] However, comparing CAD/CAM resin composite to ceramics, still raises questions about its performance.[48, 49] Recently, the popularity of 3D printed resin composite materials based on additive manufacturing technology have expanded in between clinicians to reasonable cost, less designing and fabrication time, and enhanced performance regarding accuracy, and marginal gap.[50, 51] Although several studies have been published elsewhere, the lack of scientific literature regarding the materials' inherent properties raises concerns regarding the materials' survival and anticipated mechanical complications due to the growing popularity and variety of these new materials intended for indirect restorations.

Generally in vitro studies that looked into how remaining tooth structure and restorative material affected the distribution of stress in dental structures of ETT have so far produced unclear and conflicting findings.[52, 53] Recently, the previously unreachable stress distribution areas within the tooth-restoration complex become easy to be evaluated thanks to 3D FEA modeling. Its capacity for predicting the clinical performance of recently introduced restorative materials in various cavity designs has rendered it a valuable tool in the process of understanding tooth biomechanics.[54] Therefore, a 3D finite element analysis was involved in the current study to gain a better knowledge of stress distribution in 3 D printed resin composite restorations in comparison to CAD/CAM ones in different cavity designs. The current study's stress distribution analysis was carried out following the application of a 250 N vertical loading to the central groove, which replicated the typical vertical force applied on the maxillary molars during mastication.[40] The results of VM stresses generated on the various tested models in the current study were not statistically analyzed since, according to several publications, they are not relevant to the FEA results.[55-57]

Concerning the cavity design, the color maps of the present study demonstrated that, the maximum stresses was observed at the loading points which located at enamel in case of intact tooth and at restorations in restored models. This finding is in agreement with the findings of previous studies.[58-60] Additionally, the palatal cusps of inlay and onlay models had the highest concentrations of stresses, whereas the endocrown models showed the lowest values. This results align with those of earlier researches which found that stresses are concentrated on functional cusps.[59, 61] This pattern of stress concentration could be related to chipping of the palatal occlusal margins of tooth structures with subsequent clinical failure of inlays when used to restore maxillary molars.[59] It's noteworthy to note that the colorimetric graphs of the onlay models displayed better distribution and less concentration of stresses in the tooth structure than in inlay models. This could be attributed to cusp capping, which permits better distribution of stresses to the underlying dentin in comparison to that of inlay. Therefore, cuspal coverage is mandatory in large preparations to prevent possible fracture.[59, 62] On the other side, the endocrown models of both evaluated restorative materials showed the least amount of stress transferee to enamel, dentin, and cement interface. Also, the endocrown models showed proper stress distribution through the roots surfaces although it has less amount of remaining tooth structure in comparison to both inlay and onlay cavity designs. The explanation behind this outcome could be that endocrown in the current study have advantage over both inlay and onlay models, which is presence of higher number of restorative interfaces in both inlays and onlays through using of flowable resin composite as a base in the pulp chamber of the ETT. Consequently, the endocrown decrease the impact of multiple interfaces of the restorative system. Moreover the endocrown providing a larger thickness of the restorative material gained by the extension of endocrowns into the pulp chamber with higher ability to withstand the compression stresses that may help to clarify this outcome. The same result was also obtained by Durand et al.,[63] who declared that models bonded directly to the cavity walls showed better distribution of stresses than models received resin composite bases.

Irrespective of the cavity design, color maps of the present study showed that, both tested restorative materials absorbed higher stresses than its surrounding tooth structure.[64] However, CAD/CAM resin composite restorations absorbed more VM stresses than 3D printed ones. As a consequence, each CAD/CAM restoration transferred less stresses across the adhesive cement interface to the remaining tooth structure. This finding might be explained by knowing that the Crowntec 3D printed resin composite has a lower elastic modulus than Brilliant Crios CAD/CAM material (4, 10.3 Gpa) respectively. Therefore, this result could be explained by the concept that low elastic modulus materials transferred more stress to surrounding tooth structure, while high elastic modulus materials tends to accumulate stresses within their mass.[64, 65] This explained the reason behind concentration of more stresses in dental tissue and cement layer in models restored with 3 D printed restorations in comparison to the CAD/CAM restorations that absorb more stresses and minimize stress transmission to tooth structures in all evaluated cavity designs.[65] Based on this result it could be anticipated that, the cement's bond strength is more crucial for these novel materials than for those manufactured through CAD/CAM technology as atrial to overcome the risk of their bonding failure.[66] Therefore, the current study's findings led to the rejection of the first tested null hypothesis while, accepting of the second one. A key limitation of this study is that, while FEA aids in the prediction of clinical failure, it is challenging to accurately account for all the variables that exist in clinical conditions. For example, all involved materials were assumed to be homogenous and linearly elastic, despite the fact that their actual properties may differ. Evaluating the models through application of static vertical load only however, cyclic loading is involved too in oral conditions. However, strength of the materials used to make restorations is an important factor, other factors conserving its durability during clinical performance must be taken into account for future research to fully understand their impact.

## CONCLUSIONS

Within the limitations of this study, it can be concluded that:

1. In terms of their ability to withstand stresses, endocrown rather than, onlays or inlays, should be the first restorative option for restoring endodontically treated maxillary molars that have had massive loss of tooth structure.
2. CAD/CAM resin composite material provides more protection to the remaining tooth structure in comparison to the 3D printed one.

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**Conflicts of Interest**

There were no conflicts of interest.

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