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Stress Distribution Pattern on Mandibular Molar Restored by Occlusal Veneer Effect of Veneer Material and Dental Bonding Surface

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A B S T R A C T

It was aimed to evaluate the stress distribution within and around occlusal veneers that made from; lithium disilicate, zirconia and hybrid ceramic. Occlusal veneers to be bondedin three different ways (1) ***bonded directly to dentin, (2) bonded to dentin with prepared cavity and (3) bonded to dentin with composite filling as three case.***

Using nine freshly extracted mandibular first-molar were distributed into three equal groups according to the substrate. Where group I: lithium disilicate, group II: zirconia, group III: hybrid ceramic. Bonding all occlusal veneers to its corresponding prepared teeth was carried out by using "dual cure" adhesive resin cement. In addition, tree finite element models were prepared to to evaluate the distribution of stresses exerted in eachcase .

Different occlusal veneers preparation designs showed minor differences appeared by changing restoration materials in each model. Under vertical loading zirconia occlusal veneer showed the lowest deformation followed by lithium disilicate occlusal veneer and hybrid ceramics occlusal veneer showed the highest deformations. Cement under zirconia restoration showed the lowest deformation followed by lithium disilicate and hybrid ceramics showed the highest deformations. The dentin for the model of dentin with composite filling subgroup showed the lowest stresses then the model of Dentin subgroup. Under the average biting forces, all the tested occlusal veneers preparation designs showed values of stresses within the physiological limits.

1. Introduction

Restorative dentistry aimed to preserve tooth structure. From a biomimetic perspective, equilibrium between biologic, mechanical functional, and esthetic parameters can be achieved by conservation of tooth structure.[1] Losing occlusal contact between mandibular and maxillary teeth may be referred to pathological or functional problems like teeth wear and caries or an open posterior occlusal relationship with or without orthodontic therapy. Dental problems might include a reduction of masticatory efficiency, loss of vertical dimension, hypersensitivity, and discoloration.[2,3] "Patients with advanced wear treatment is challenging. That is due to the huge complications like; possible wear compensation by tooth eruption (preserving dimension) and further reduction of sound tooth structure to restore worn teeth. There is a huge varity in the reduction amount for different restorations.[4-6] Conventional full crowns can be manufactured to treat cases of worn dentition. However, full-coverage crowns usually involve the removal of additional tooth structure can ensure feasible and esthetic restoration, application. Patients with significant loss of tooth tissue on long-term viability of the teeth will be lost.[6-8] Occlusal veneer restorations to recover the occlusal surface (vertical dimension) for patients with large occlusal wear due to parafunctional habits and/or physiological processes such as erosions.[7,9,10] Where, the main advantage of occlusal veneers is the recovery of the masticatory.[4,11-13]"

Glass ceramics are usually recommended as suitable material for indirect minimally invasive treatment approaches.[14] On the other hand, using glass ceramic for restoration in the posterior area "in reduced thicknesses" might led to high technical complications.[15-17] Previous studies that involved ultrathin composite or ceramic veneers pointed the complications as; de-bonding, cracks or chipping and fractures limited to the restorative material.[18,19] One strategy to optimize the mechanical performance of restorative material, is utilizing

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ceramic with higher fracture toughness and higher flexural strength relative to other conventional ceramics.[13] Translucent zirconia as an esthetic material, encourage the manufacturing of crowns and fixed prostheses (anterior or posterior), including veneers and ultrathin occlusal veneers.[20-22]"

Loading structure generate stresses inside the material. These stresses, their magnitude, distribution and orientation depend not only on the geometry of the structure but also on the loading configuration and the properties of the materials.[23,24] Finite Element Analysis is a significant research tool for biomechanical analyses in dental research. [25-31] The aim of this study was to assess the effect of occlusal veneer materials (lithium disilicate, zirconia, hybrid ceramic) and dental bonding surfaces (dentin, dentin with prepared cavity, and dentin with composite filling) on the stress distribution for a mandibular first molar restored with occlusal veneers, following different loading conditions. The null hypotheses were; (1) no differences expected in stress distribution by changing veneer materials, (2) differences may exist in stress distribution based on different bonding surfaces.

2. Materials and Methods

"This research methodology was approved by the appropriate research ethics committee (No. M 2110220). Nine intact human mandibular first molars, freshly extracted due to periodontal reasons, with similar dimensions, to form nine groups as listed in (Table 1). Preparation of each tooth was performed by single operator (D.R) using straight hand-piece (FX 65, NSK, Japan) with utilizing paralleling device (103 Surveyor, Marathon, China). For all teeth, 2 mm reduction of the occlusal surface was done at the cusp tip and central groove, that, following the occlusal anatomy while creating divergence angle of 150° between tooth cusps. The intra-coronal cavity (for LC, ZC, HC, LF, ZF, and HF groups) was prepared using a diamond stone (856 blue, FG, Switzerland). The intra-coronal cavity had 1mm pulpal depth, and 2mm bucco-lingual width, with 8º wall taper, and 1.6 away from the proximal marginal ridge. The intra-coronal cavities for LF, ZF, and HF groups were etched using 9% hydrofluoric acid etching gel (N-Etch Ivoclar Vivadent, Schaan, Liechtenstein) for 20 seconds. Then rinsed and dried, for bonding agen (Tertric N-Bond Universal) to be applied and light activated at each surface for 20 seconds. After that, composite resin (Tetric N-Ceram Bulk-Fill Composite Ivoclar Vivadent, Schaan, Liechtenstein) was used to fill the cavity and light activated for 20 seconds. Finally, all teeth were finished by utilizing tapered round end diamond stone (856 yellow, FG, Switzerland).

For fabrication of occlusal veneers, the teeth were scanned using an extra-oral scanner (ldentica scan version 1.0.3.6, Medit.Seoul, Korea). Each restoration was designed using CAD-CAM software (Exocad GmbH; Fraunho fer IGD, Damsta dt, Germany Version 2015). The cement gab was set at 40 µm. The thicken of all veneer restorations were 1 mm (except at cavity projections with LC, ZC, and HC groups). Then, the restorations were milled (Imes-Icore 250i, Coritec, Germany) from lithium disilicate (IPS e.max CAD, Ivoclar Vivadent, Liechtenstein), zirconia (Katana UTML Kuraray Noritake Dental Inc., aisha, Japan.), and hybrid ceramic (Vita Enamic, VITA Zahnfabrik, Badsackingen, Germany). After milling, Lithium disilicate restorations were subjected to crystallization and glaze firing according to manufacturer's recommendations. Zirconia restorations were sintered and glazed according to manufacturer's recommendations. Hybrid ceramic restorations were finished and glazed according to manufacturer's recommendations.

According to manufacturer's instruction, the intaglio surfaces of E.max (lithium disilicate) and Hybrid ceramic occlusal veneer(s) were treated using "9.5% hydrofluoric acid" (Porcelain Etchant, Bisco, USA) for 60 seconds. The intaglio surfaces of zirconia occlusal veneers were air-borne particle abraded with 50 µm alumina at a pressure of 60 psi (0.4 MPa) from 10 mm distance. All the occlusal veneers were silanated (Z-Primer Plus, Bisco, USA). The teeth surfaces were prepared by using acid etching using 37% Phosphoric acid (N-Etch, Ivoclar Vivadent, schaan, Liechtenstein). Then, the bonding agent (All-Bond Universal, Bisco, USA) was applied and cured. Finally, as recommended by the manufacture, each restoration was bonded to its corresponding tooth (Figure 1) using an adhesive resin cement (Duo-Link Universal, Bisco, USA).

Three 3D finite element models of mandibular first molars were constructed simulating the three cases: first model (veneer bond to dentine); second model (veneer bond to prepared dentine); and third model (dentin with composite filling) where each was tested with the three materials (*lithium disilicate, zirconia and hybrid ceramic*). The 3D models were obtained by 3D scanning of a sample mandibular first molars molar tooth. The tooth geometry was acquired using laser scanner (Geomagic Capture, 3D Systems, Cary, NC, USA). Such type of scanners generated file(s) containing huge cloud of points' space coordinates. Rhino Version 3.0 (McNeel inc., Seattle, WA, USA) as an intermediate phase was utilized to trim the newly created surface(s), that connecting sets of the acquired points. Finally, the closed tooth outer surfaces "called outer geometry" was exported in STEP file format to the finite element analysis package. On the other hand, both bone types geometries were simplified and replaced by two co-axial cylinders. Where, the internal cylinder represented trabecular bone (with 14mm outer diameter and 22mm height). The outer cylinder represents the cortical bone with a shell of 1 mm thickness (16 mm outer diameter, 24 mm height). Boolean operations were performed to generate cement layer of 40 µm around the coping, in addition to create roots' cavity inside bone on the finite element package finalize the required three models' geometries."

Boolean and assembly of the three models' components took place on ANSYS version 16 (ANSYS Inc, Canonsburg, PA, USA). The final tooth geometry and models' parts from ANSYS screen are shown in Figures 2-4. Three models were constructed to simulate restoration of occlusal veneer in the clinical cases to restore the occlusal vertical dimension(s) for patient(s) with great occlusal wear that might related to parafunctional habit(s) or physiological processes such as erosions.

Table 2 listed the used materials in this study, that were assumed to be; (1) homogenous, (2) isotropic and (3) linear elastic.[32] The meshing the models' components were performed by "parabolic tetrahedral element", that adequate mesh size was

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selected to achieve acceptable results accuracy. Table 3 listed the mesh density (number of nodes and number of elements) of all models' components.

Loading and boundary conditions: Two loading cases were applied to each model as; (1) Vertical loading of 200 N, (2) Oblique loading of 45 N, both to be applied at the occlusal central fossa, and the buccal surface of the buccal cusp.[32] The lower surface of the cortical bone (hollow cylinder of 1mm thickness) was set to be fixed in place as a boundary condition. Thus, totally eighteen runs were performed on the three models.

The solid modeling and linear static finite element analyses were performed on a Workstation HP Z820, with Dual Intel Xeon E5-2660, 2.2 GHz processors, 64 GB RAM.

3. Results"

Restoration results comparison (Figure 5): Oblique loading exert higher stresses on restoration than vertical loadings. On the other hand, total deformations showed opposite behavior that vertical loading caused less deformation than oblique ones. Minor differences appeared by changing restoration materials among the three restorations' designs. Whatever the restoration material, for the model of LF, ZF and HF subgroup showed the lowest stresses then model of LD, ZD and HD subgroup and the highest values appeared on model of LC, ZC and HC subgroup. Under oblique loading and for the same restoration design, no significant was recorded. While, under vertical loading zircon restoration showed the lowest deformation followed by LC and HC showed the highest deformations.

Cement results comparison (Figure 6): Oblique loading exert higher stresses on restoration than vertical one. On the other hand, total deformations showed opposite behavior that vertical loading caused less deformation than oblique ones. Minor differences appeared by changing restoration materials among the three restorations' designs. Whatever the restoration material, the cement for the model of LF, ZF and HF subgroup showed the lowest stresses then the model of LC, ZC and HC subgroup and the highest values appeared on the model of LD, ZD and HD subgroup. Under oblique loading and for the same restoration design, no significant was recorded. While, under vertical loading zirconia restoration showed the lowest deformation followed by lithium disilicate and hybrid ceramics showed the highest deformations.

Dentin results comparison (Figure 7): Oblique loading exert higher stresses on restoration than vertical one. On the other hand, total deformations showed opposite behavior that vertical loading caused less deformation than oblique ones. Minor differences appeared by changing restoration materials among the three restorations' designs. Whatever the dentin, for the model of LF, ZF and HF subgroup showed the lowest stresses then the model of LD, ZD and HD subgroup and the highest values appeared on model of LC, ZC and HC subgroup. Under oblique loading and for the same restoration design, no significant was recorded. While, under vertical loading zirconia restoration showed the lowest deformation followed by lithium disilicate and Hybrid ceramics showed the highest deformations.

Enamel results comparison (Figure 8): Oblique loading exert higher stresses on restoration than vertical one. On the other hand, total deformations showed opposite behavior that vertical loading caused less deformation than oblique ones. Minor differences appeared by changing restoration materials among the three restorations' designs. Whatever the enamel, for the model of LF, ZF and HF subgroup showed the lowest stresses then model of LC, ZC and HC subgroup and the highest values appeared on Model of LD, ZD and HD subgroup. Under oblique loading and for the same restoration design, no significant was recorded. While, under vertical loading hybrid ceramics showed the lowest deformation followed by lithium disilicate ceramics and zirconia showed the highest deformations.

Cortical Bone result comparison (Figure 9): Oblique loading exert higher stresses on restoration than vertical one. On the other hand, total deformations showed opposite behavior that vertical loading caused less deformation than oblique ones. Minor differences appeared by changing restoration materials among the three restorations' designs. Whatever the cortical bone, for the model of LF, ZF and HF subgroup showed the lowest stresses then the model of LC, ZC and HC subgroup and the highest values appeared on the model of LD, ZD and HD subgroup. Under oblique loading and for the same restoration design, no significant was recorded. While, under vertical loading zirconia restoration showed the lowest deformation followed by lithium disilicate and hybrid ceramics showed the highest deformations.

Spongy Bone results comparison (Figure 10): Oblique loading exert higher stresses on restoration than vertical one. On the other hand, total deformations showed opposite behavior that vertical loading caused less deformation than oblique ones. Minor differences appeared by changing restoration materials among the three restorations' designs. Whatever the restoration material, for the model of LD, ZD and HD subgroup showed the lowest stresses then the model of LF, ZF and HF subgroup and the highest values appeared on Model of LC, ZC and HC subgroup. Under oblique loading and for the same restoration design, no significant was recorded. While, under vertical loading zircon restoration showed the lowest deformation followed by LDC and HC showed the highest deformations.

4. Discussions

The null hypotheses during this research were; (a) stress distribution for the restored mandibular first molar would not alter with different occlusal veneer material, and (b) the different loading condition would alter the stress distribution for the restored mandibular first molar. The both proposed hypotheses were accepted.

In the current study, Lithium disilicate, zirconia, and hybrid ceramic materials were selected to construct the occlusal veneer restorations. The main advantages of using lithium disilicate glass-ceramics are; (1) better esthetics, (2) similar wear behavior to enamel, (3) ability to be etched & salinized, and (4) lower processing temperatures.[7] "In addition, it appeared; (5) more suitable for ultra-thin onlays, (6) large occlusal veneers. Even in partial-coverage crowns it ensures long-term success of posterior partial coverage restorations.[13] Higher fracture resistances of lithium disilicate restorations bonded to enamel was recorded in comparison to those having dentin as substrate.[17] however, it was recommended that a thickness of 1–1.2 mm should be used with lithium-disilicate partial restorations.[13] Flexural fracture resistance of lithium disilicate onlays is higher, in case of supporting by enamel, relative to case of dentin support, that may be attributed to the smaller mismatch in physical properties (elastic modulus) between lithium disilicate and enamel.[7] Zirconia can withstand high masticatory forces,[13] thus, zirconia become the preferred choice for posterior restorations due to its mechanical properties.[7,21,26] In addition, Zirconia is superior to many other material that used in tooth-colored restoration. Zarone et al, reported in a review article that, the stress rate of zirconia itself was low or non-existent.[17] As the restoration material approaches the dentin structure (elastic modulus), like hybrid ceramic materials showed the lowest failure risk for the crown and its cement layer.[27]

In the present study, three preparation designs were studied. The first preparation design (LD, ZD and HD) represents a non retentive design for "occlusal veneer preparation" that have excellent reputation by time as conservative minimally invasive treatment in severely worn dentition cases.[6,28,34] Further modification to this basic design that aiming to improve the bonding to substrate(s). That makes use of the second studied preparation design (LC, ZC, and HC), which might improve fracture resistance through cuspal coverage.[6,28] Regarding the modified intra-coronal extension occlusal veneer preparation design, it was employed to make use of a pre-exiting cavity in retention of the occlusal veener.[28] this design showed high values of Von Misses stress on; dentin, enamel and occlusal veneer–tooth restoration. Where, wedging action might transfer high percentage of occlusal loads to the cervical area of the tooth, that might resulting in failure(s).[6,35]

In the current study, all values of deformations and stresses appeared on all model components (veneer material, composite filling, enamel, dentin, cortical bone, and spongy bone). The obtained results within this research are in good agreement with Kotb et al[28] finding, where, it was done by using of the maximum chewing forces in the posterior molar region (ranged between 200 to 540N), noting that, these values might dramatically increase to about 800N with bruxism.

As shown in the present study, the minor differences appeared by changing restoration materials in each model. Whatever the model that used restoration materials showed equivalent (very close to each other) values of deformations and stresses under similar conditions.

The results during this study showed very good agreement with Sasse et al[6] results, when evaluated the role of ceramic thickness and ceramic type (at dental bonding surface), on the fracture resistance of non-retentive full-coverage adhesively retained " lithium disilicate ceramic" occlusal veneers. They concluded that, in regard to finite element analysis (or stress distributions), the information about reliability of thin CAD/CAM all ceramic occlusal veneer(s) and the influence of different preparation design on the performance of these restorations are still not enough.

Stress distribution in the ceramic veneers in a full prosthetic crown, was evaluated by Carvalho et al[24] with different framework(s) by using 3D finite element analysis. The thermal study analysis was done for crowns after the sintering and cooling cycle through. It was showed that the pattern of stress distribution did not change with the use of different materials. However, the results in the present study are in disagreement with the finding in a study done by Maria et al[27] investigated the role of using different materials for monolithic full posterior crowns by using three dimensional FEA. Their results showed that, the high peak(s) of stresses appeared on the crowns were recorded with the higher modulus of elasticity materials. While, the pattern of stress distribution did not change with the use of different materials.

In the current study and whatever the loading condition, negligible differences were recorded on cement deformations by changing restoration materials. Such differences may be referred to restoration material stiffness (related to modulus of elasticity). As the restoration material stiffness increased the cement showed less deformations due to better load distribution. Maria et al[27] investigated the influence of using monolithic full posterior crowns' different materials for using three dimensions FEA. They reported that, cement layer was ignored during the study, and showed that high stress at the interface might referred to the difference between materials modulus of elasticity of the substrate and the restorative material. Ma et al[7] investigated the monolithic zirconia and lithium disilicate capability to withstand applied loads. Results pointed that, modulus of elasticity minor mismatch between the lithium disilicate and its supporting tooth structure was great advantage in comparison to zirconia. In addition, results showed that due to the cement low modulus of elasticity value in comparison to enamel, the cement layer might affect ceramic load bearing capacity. Tribst et al[5] studied the stress distribution appeared on; occlusal veneer different materials, restoration thickness, and cement layer thickness. They indicated that; the thickness of the cement layer negligibly affect the restorations mechanical behavior. In addition, thicker occlusal veneers improved the mechanical performance, under the usual masticatory forces. Maria et al[27] studied the effect of using different types of monolithic full posterior crowns materials using three dimensional FEA. The conclusion was that the materials with higher modulus of elasticity (like Co–Cr, zirconia and alumina) might cause higher tensile stress concentration on the crown intaglio surface and higher shear stress on the cement layer."

In the current study, in model LF, ZF and HF preparation, the stresses of cement close to the control model, due to having close properties to dentin. While model LC, ZC and HC preparation inverted the trend of stresses in comparison to the other two models due to the cavity filling with hard materials (restoration materials). "Damla and Sener[29] checked three different inlay materials (composite, glass ceramic, and zirconia), and their effect on cavity design parameters (isthmus width and depth) under different loading conditions by estimating the stress and deformation distribution(s) within; mesio-occlusal-distal (MOD) inlays, remaining enamel and dentin. Using finite element method, the stresses between the internal surfaces of the ceramic inlays were calculated. The resin composite and the latter were recommended to limit the forces transmitted to the remaining tooth structure(s). However, Magne et al[12] investigated and compared the exerted stresses within bonded porcelain and composite resin (ultra-thin occlusal veneer) to restore advanced erosive lesions. The prepared numerical model results showed that; composite resin dissipate more stresses. Additionally, Alsadon et al[22] checked the stress concentration and fracture resistance on zirconia-composite veneered crowns in comparison to zirconia-porcelain crowns, using three dimensional finite element method. The conclusion was that the higher stresses on composite were generated under the base of zirconia based crown(s) under average occlusal loads.

In the current study, the enamel deformations have negligible differences between different restoration material from the deformation point of view. That may be referred to small cavity size and its site far enough from enamel to cause effect. Yamanel et al[30] checked the effects of different inlay and onlay cavities restoration materials, and found that the ceramic inlay material generated less stresses on the tooth structure(s) in comparison to onlay. However, Costa et al[31] analyzed maxillary canine tooth to find the role of thickness and incisal extension of indirect veneers on the stress and strain distributions. The conclusion showed insignificant effect on the stress distribution on the remaining tooth structure exerted between preparation(s) and veneer extension.

In the current study, the minor differences on enamel Von Mises stress were recorded between lithium disilicate and zirconia restoration on each model due to higher restoration modulus of elasticity than enamel. On the other hand, Hybrid ceramic the weakest restoration material absorb the load energy and minimum effect appeared on enamel layer. Yamanel et al[30] studied the effect of different inlay and onlay cavities restored by ceramic and composite materials using three dimensional FEA. Results showed that generally ceramic inlays and onlays created low stress levels on the tooth structures in comparison to composite resin one(s). Oyar et al[8] compared, anatomic and non-anatomic occlusal preparation designs, effect on the stress distribution generated on all ceramic crowns and underneath structure(s). They were concluded that, no significant effect was recorded on amount or distribution of stress in tooth structure under different ceramic material(s).

The results obtained within this study are matching the findings of Maria et al[27]. Who studied different materials for monolithic full posterior crowns and their effect on the generated stresses by using three dimensional FEA. As the hybrid ceramic has modulus of elasticity is similar to dentin, it was concluded that, it reduced the stresses on the crown and tooth, while negligible stresses changes was obtained on the cement layer. Kotb et al[28] studied fatigue resistance and generated stress distribution(s) of bonded occlusal veneers (two modified occlusal veneer preparations), and compare it the conventional preparation design(s). The modified design of intra-coronal extension occlusal veneer results were very high values of Von Misses stress appeared on enamel and the occlusal veneer.

In the current study the dentin deformations were minor affected LC, ZC and HC preparation or LF, ZF and HF preparation. While it is insensitive to restoration material. Von Mises stress exerted on dentine strongly affected by restoration material and cavity or its filling material. The higher restoration material rigidity (correlated to modulus of elasticity) the higher dentine stresses in models LC, ZC and HC preparation and LF, ZF and HF preparation. This is clearly related to existence of restoration material inside cavity, while dentine of LD, ZD and HD preparation was showing opposite behavior. Yamanel et al[30] showed that the dentin Von Mises stress values were higher in case of inlay cavity design than the obtained one in case of onlay cavity design. Afonso et al[36] shot molar cavity preparation and ceramic type effects on the stress and strain distributions, fracture resistance and fracture mode when restored with onlay(s). Better biomechanical behavior was recorded by the onlay ceramic with conservative preparation (without occlusal and proximal boxes) in comparison to conventionally prepared ceramic onlay restorations.

In the current study the cortical and spongy bone are insensitive to cavity type or cavity filling material (composite or restoration). That may be referred the relative volumetric size between original dimensions and cavity, in addition to changes effect will be imbedded in dentin. Oyar et al[8] investigated the expected effects of preparation designs; anatomic occlusal, and non-anatomic occlusal, on the stress distribution appeared on underneath structures, where, no significant differences was recorded by using different ceramic materials in both designs.

5. Conclusions

Within the obtained results during this in-vitro study, the following conclusions could be drawn:

1. Different occlusal veneer preparation designs using lithium disilicate, zirconia and hybrid ceramics, showed lower stress in zirconia occlusal veneer, compared to other materials
2. The LF, ZF and HF subgroup can be conservative and safe to use as a restoration to worn posterior teeth.
3. The three tested models, for different occlusal veneers preparation designs, showed values of stresses and deformations within the physiological limits under the average biting force(s).

6. Tables and Figures

Table 1: Study grouping.

Code	Group
LD	Lithium disilicate occlusal veer bonded to dentin
LC	Lithium disilicate occlusal veer bonded to dentin with prepared cavity
LF	Lithium disilicate occlusal veer bonded to dentin with filling composite
ZD	Zirconia occlusal veer bonded to dentin
ZC	Zirconia occlusal veer bonded to dentin with prepared cavity
ZF	Zirconia occlusal veer bonded to dentin with filling composite
HD	Hybrid ceramic occlusal veer bonded to dentin
HC	Hybrid ceramic occlusal veer bonded to dentin with prepared cavity
HF	Hybrid ceramic occlusal veer bonded to dentin with filling composite

Table 2: Materials properties used in the analysis [32]

Material	Young's modules [GPa]	Poisson's ratio
Lithium disilicate ceramic	34.5	0.24
Zirconia Restoration	103.0	0.25
Hybrid ceramic	210.0	0.24
Cement (Resin type, of 40μm)	8.3	0.35
Composite filling	20.0	0.25
Enamel	84.1	0.33
Dentin (core + Root)	18.6	0.31
Cortical bone	13.7	0.30
Cancellous bone	1.37	0.30

Table 3: Mesh density.

Component	Model #1		Model #2		Model #3	
	No of nodes	No of elements	No of nodes	No of elements	No of nodes	No of elements
Cortical bone	25.137	13.000	25.137	13.000	25.137	13.000
Spongy bone	89.372	53.632	89.372	53.632	89.372	53.632
Enamel	67.657	3.727	67.801	37.373	67.801	37.373
Dentine	177.813	104.402	174.802	102.171	174.802	102.171
Composite	-----	-----	439	60	-----	-----
Cement	72.923	36.255	67.792	33.820	60.034	29.787

Restoration	57.588	32.867	57.588	32.867	60.960	35.544

Figure 1: The occlusal veneer during cementation to its corresponding tooth.

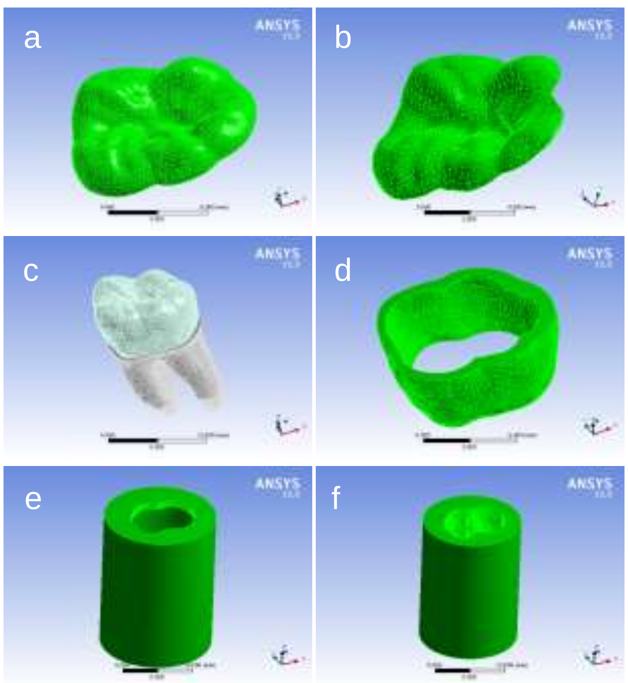


Figure 2: Model #1 (*dentin*) for the mandibular first molars for LD, ZD and HD subgroup; A: Occlusal veneer, B: Cement layer, C: Dentin, D: Enamel, E: Cortical bone, and F: Spongy bone.

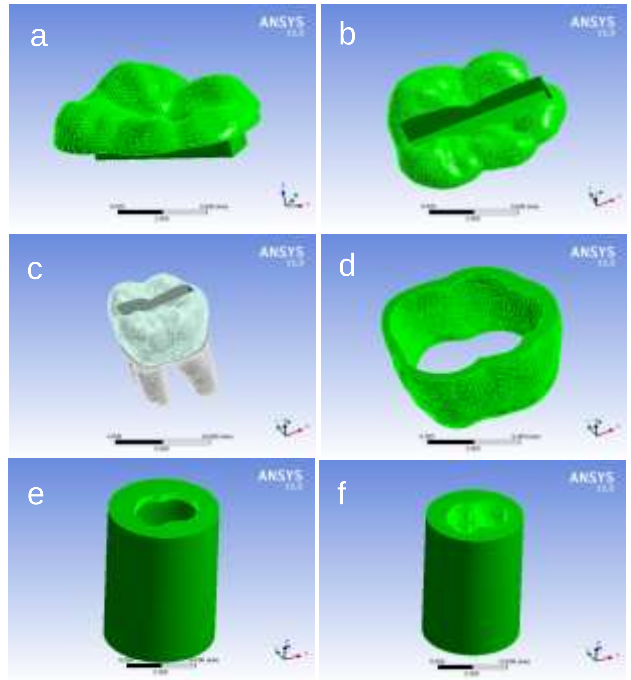


Figure 3: Model #2 (*dentin with prepared cavity*) for the mandibular first molars for LC, ZC and HC subgroup; A: Occlusal veneer, B: Cement layer, C: Dentin, D: Enamel, E: Cortical bone, and F: Spongy bone.

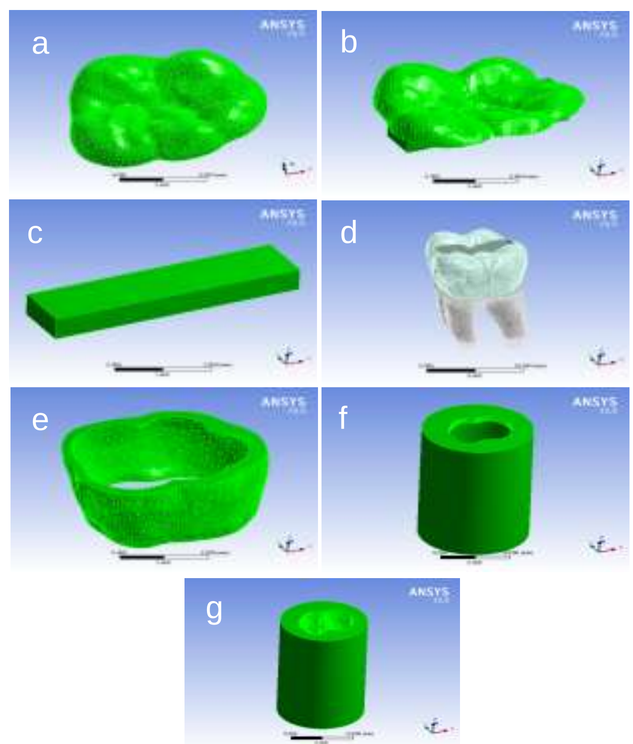


Figure 4: Model #3 (*dentin with composite filling*) for the mandibular first molars for LF, ZF and HF subgroup; a: Occlusal veneer, b: Cement layer, c: Composite, d: Dentin, e: Enamel, f: Cortical bone, and g: Spongy bone.

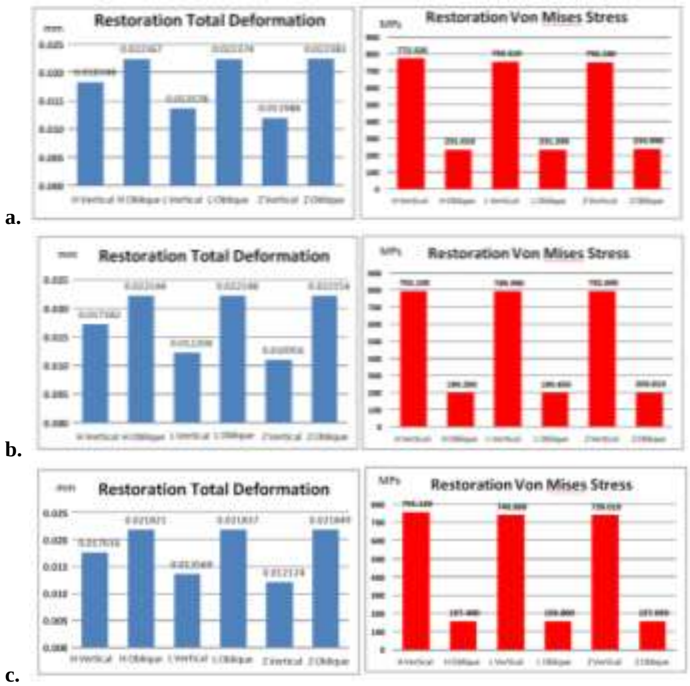


Figure 5: Comparison between extreme values of total deformation and Von Mises stress for all study groups regarding restoration types; (a) Group I, (b) Group II, and (c) Group III.

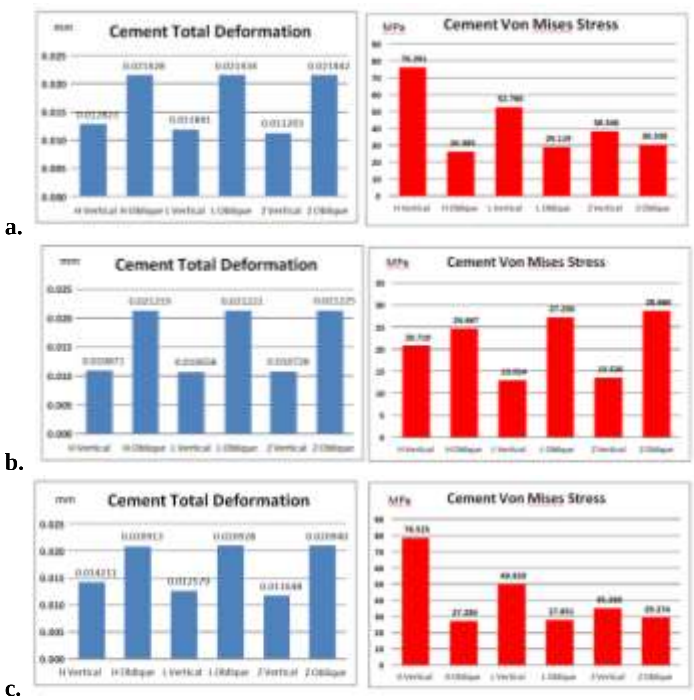


Figure 6: Comparison between maximum values of total deformation and Von Mises stress for all study groups regarding cement layer; (a) Group I, (b) Group II, and (c) Group III.

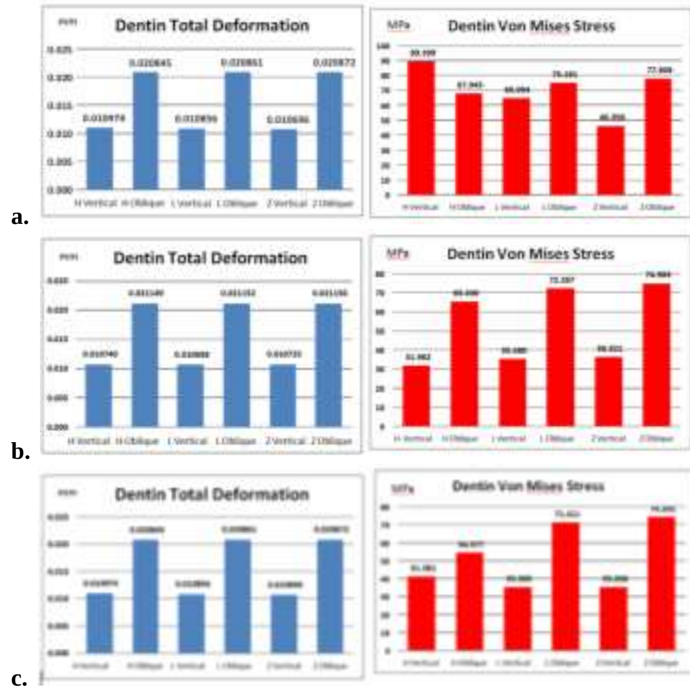


Figure 7: Comparison between maximum values of total deformation and Von Mises stress for all study groups regarding dentin; (a) Group I, (b) Group II, and (c) Group III.

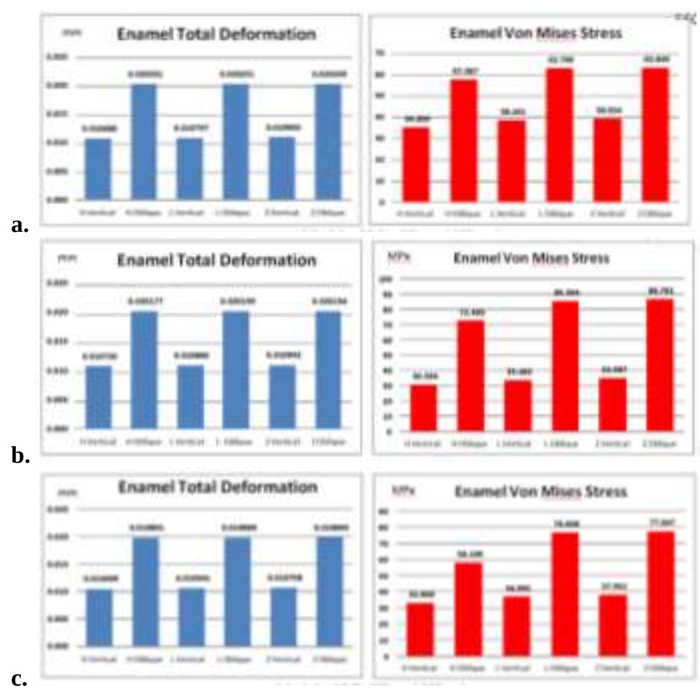
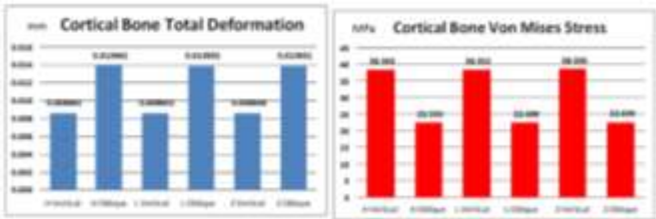
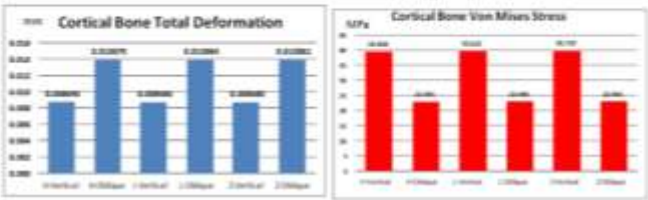


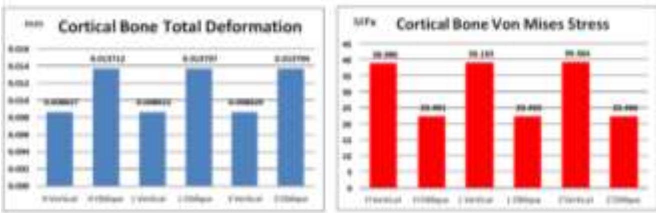
Figure 8: Comparison between maximum values of total deformation and Von Mises stress for all study groups regarding enamel; (a) Group I, (b) Group II, and (c) Group III.



a.

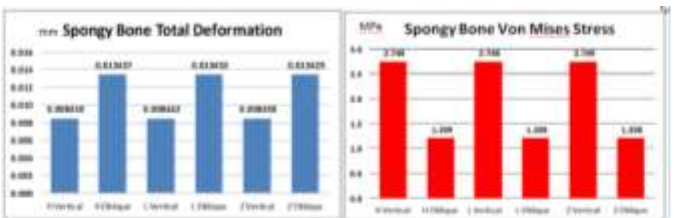


b.

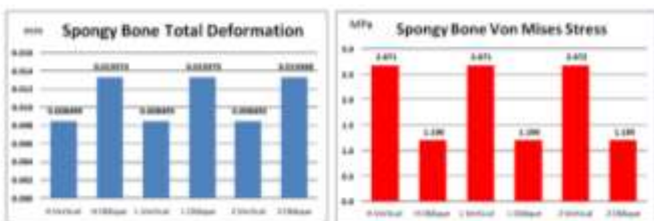


c.

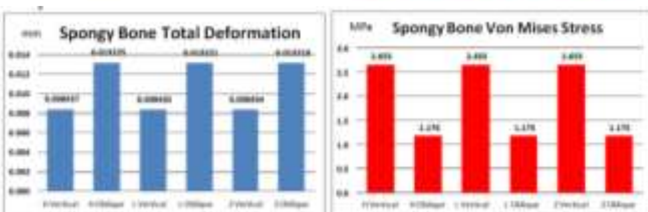
Figure 9: Comparison between maximum values of total deformation and Von Mises stress for all study groups regarding cortical bone; (a) Group I, (b) Group II, and (c) Group III.



a.



b.



c.

Figure 10: Comparison between maximum values of total deformation and Von Mises stress for all study groups regarding cancellous bone; (a) Group I, (b) Group II, and (c) Group III.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgment

N/A

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