BJOS
Brazilian Journal of Oral Sciences

Original Article

Volume 22
2023
e230356

Influence of the cervical margin relocation on stress distribution - a finite element analysis on lower first molar restored by direct nano-ceramic composite

Nabil al Aggan[1,*], Sameh Mahmoud Nabih[2], Abd Allah Ahmed Abd Al Hady[3]

[1] Assistant Lecturer in Operative Dentistry Department, Faculty of Dental Medicine, Al–Azhar University (boys-Cairo)

[2] Professor of operative dentistry and Vice dean for Post Graduate affairs, Faculty of Dental Medicine, Al–Azhar University (boys-Cairo)

[3] Assistant Professor in Operative Dentistry Department, Faculty of Oral and Dental Medicine, Al–Azhar University

Corresponding author:
Nabil Al Aggan
n.a.a.elagan@gmail.com

Editor: Dr. Altair A. Del Bel Cury

Received: July 11, 2022
Accepted: November 4, 2022

Aim: Evaluate the influence of the cervical margin relocation (CMR) on stress distribution in the lower first molar restored with direct nano-ceramic composite (zenit). **Methods:** A 3D model of the lower first molar was modeled and used. Standardized mesio-occluso-distal (MOD) preparation consisted in two models used in this study with mesial subgingival margin in model II. (CMR) was applied in model II using flowable composite or resin glass ionomer (Riva). Both models were restored with nanoceramic composite and then subjected to six runs (2 for the model I and 4 for model II) with load (100N) as two load cases, one at (11º) and other at (45º) from the vertical axis. The stress distributions (FEA) in the final restoration and (CMR) material were analyzed using 3D models. **Results:** The two models recorded an equivalent Von Mises stress and Total deformation in the final restoration, regardless of the difference in the oblique angle incidence from (11º to 45º) or the type of the material used for (CMR) there was no significant difference in the (FEA) between the model with CMR (model II) and the model without CMR (model I). **Conclusions:** (CMR) technique seems to be biomechanically beneficial with high eccentric applied stress, (CMR) with resin glass ionomer or flowable composite resin in combination with nanoceramic composite improved the biomechanical behavior of (MOD) cavities extended below cement enamel junction (CMR) with high modulus elasticity material like (Riva) exhibits a more uniform stress distribution.

Keywords: Finite element analysis. Composite resins. Glass ionomer cements.

Introduction

Long-term clinical observations showed that even large cavities encompassing three or more surfaces and cusps of load-bearing posterior teeth can be restored successfully with minimally invasive direct restoration techniques. However, direct restoration of deep proximal defects beyond the cemento enamel junction (CEJ) requires elaborate treatment techniques and considerable operator skill[1,2].

(CMR) technique has been proposed as a non-invasive pretreatment for the restoration of deep Class II cavities with proximal cervical margins extending below (CEJ)[3,4]. (CMR) is an alternative for performing surgical crown lengthening and offers the possibility of a stepwise relocation of deep proximal margins to uplift cavity outlines for direct or indirect restorations[5,6]. Step one consists of placing a base of flowable or direct resin composite to elevate the margin above the (CEJ). Step two allows the practitioner to decide on whether to place a direct or an indirect restoration according to the restoration of choice under improved clinical conditions[5,6].

With current adhesive technology and modern composite resin materials it has become possible to restore even severely damaged teeth and undermine tooth defects using direct composite resin materials such as nano-ceramic composite[6,7].

Restorations should be strong enough to resist the intra-oral forces; in fact, as a result of bite forces, restored teeth are exposed to high mechanical stresses[8]. Therefore, biomechanical principles have an important part in the clinical success of restorative materials[8]. Classical methods of mathematical stress analysis are extremely limited in their scope and are inappropriate for dental structures that have an irregular structural form and complex loading[9].

Currently, (FEA) is a numerical method for stress analysis. It involves a set of computational procedures to calculate the stress and strain in each component, generating a model solution[10]. The development of technology enabled (FEA) to evolve from two-dimensional to three-dimensional modeling. The difference between 2D and 3D modeling is that 3D models are more realistic and have a closer to reality representation of the biomechanical interactions in the human anatomy, restorations, and implant components[10,11].

Stresses acting upon the materials during function in the oral cavity are Normal or Principal stress which acts perpendicular to the cross section and causes elongation or compression and shear stress which acts parallel to the cross section and causes distortion (changes in original shape)[11]. The main advantages of (FEA) are the variables can be easily changed, simulation can be performed without the need of the patient, it offers maximum standardization, and it helps to visualize the point of maximum stress and displacement. However, it is not easy to predict failure in complex designs made of different materials and complex loading varying in relation to time and point of application[12]. It is now considered the most theoretically accurate method of solving equations involving compatibility and elasticity. Finite elements are fundamental when analyzing bone and tooth failure as these are intimately connected with stress and strain behavior[10,12]. Null hypothesis of the present study is that the (CMR) has an adverse effect on (FEA) of restored teeth.

The aim of this study was to evaluate the influence of the (CMR) on stress distribution (FEA) on the lower first molar restored by direct nano-ceramic composite (Zenit).

Materials and methods

This in-vitro study was performed to evaluate and compare the influence of the (CMR) on (FEA) on the lower first molar restored by direct nano-ceramic composite (Zenit). Two models were used in this study; standardized MOD cavity preparations were performed in the two models where proximal margins were located 2 mm above (CEJ) in (moodle1) and in (model II) the mesial proximal margin located 1 mm below (CEJ)[10].

The generalized steps to perform a finite element analysis can be summarized as follows

1. Model scanning
2. Geometric model preparation.
3. Definition of the materials properties.
4. Mesh generation (nodes and elements generation).
5. Application of load, and boundary conditions.
6. Obtaining the data of resultant stresses and comparing the results[10,12,13].

1. Model scanning

A Three dimensional (3D) finite element model was constructed by 3D scanning of a sample tooth (lower first molar). The teeth geometry was digitized with a laser scanner (Geometric Capture, 3D Systems, Cary, NC, USA). Such a scanner produced a data file containing a cloud of points coordinates. An intermediate software was required (Rhino 3.0 - McNeel inc., Seattle, WA, USA) to trim a newly created surface by the acquired points. Then, the solid (closed) teeth geometry was exported to a finite element program as STEP file[10,12,13]. Standardized mesio-occlusal-distal (MOD) preparation consisted in two models used in this study with mesial subgingival margin in model II. (CMR) was applied in model II using flowable composite or resin glass ionomer (Riva).

2. Geometric model preparation

First, we set up the directions (top, bottom, mesial, distal, anterior, posterior). Then, we set up the mask thresholds to define the mask of enamel and the mask of dentin to define tooth tissues with its mechanical properties and finally, we calculate 3D objects[10,12,13]. We used a “cut orthogonal to screen” tool to cut through the tooth to reproduce the MOD of the molar, then we formed the pulpal extension part by cutting in the facial aspect and proximal surface of the molar, then the two parts were merged to form the whole MOD[10,12,13]. Then all the dentin parts were merged then the enamel part was constructed to be applied in the finite element analysis test with its mechanical properties[10,12,13]. After applying a set of Boolean operations (add, subtract, overlap, etc.) the two models' parts were ready for material assignment and meshing. Thus model I can be defined as no dentin removal under (CEJ) while model II can be defined as 1mm dentin removal under C.E.J. The 1mm dentine removed from root geometry under (CEJ) was restored by Dynamic flow flowable composite and Riva light cure glass ionomer as two case studies[10].

3. Definition of the material properties

For linear static stress analysis, there are two essential parameters that need to be defined; elastic (Young's) modulus and Poisson's Ratio, which are enough for defining the linear part of the stress strain curve of any isotropic material. The properties of the materials used in the present study were listed in Table 1 .

Table 1. Material's properties of models' components.

Materials	Modulus of elasticity in MPa	Poisson' s ratio	
Enamel	80,350	0.33	Ref 8
Dentin	19,890	0.31	Ref 8
Zenit	18754	0.3	Ref 14
Dynamic flow	5,300	0.28	Ref 15
Riva glass ionomer	10,860	0.3	Ref 8

4. Mesh generation (Nodes and Elements generation)

Each component of the model was assigned to a material property on the finite element package ANSYS Workbench version 16 (ANSYS Inc., Canonsburg, PA, USA). Then a parabolic tetrahedral element was used for meshing the model, and adequate mesh density was selected to ensure results accuracy for the discrete model[10,12,13].

5. Application of load and boundary conditions

After the models were meshed, two different oblique forces each of 100N[14-16] were applied as two load cases, one at (11º)[10] and the other at (45º)[10,14-18] from the vertical long axis of the tooth. Each load was equally divided on 15 points representing; outer, inner surface cusp tips of labial cusp, inner surface of lingual cusp, central and mesial triangular fossa distal and mesial marginal ridge[18] as presented in (Figure 1). Thus, totally six runs were performed on the two models as following:-Two runs on the model1 (one at 11º and other at 45º) from vertical axis and four runs on CMR materials of model II (one run at 11º and other at 45º on Dyract Flow) & (one run at 11º and other at 45º on Riva light cure glass ionomer) from the vertical axis[10,13].

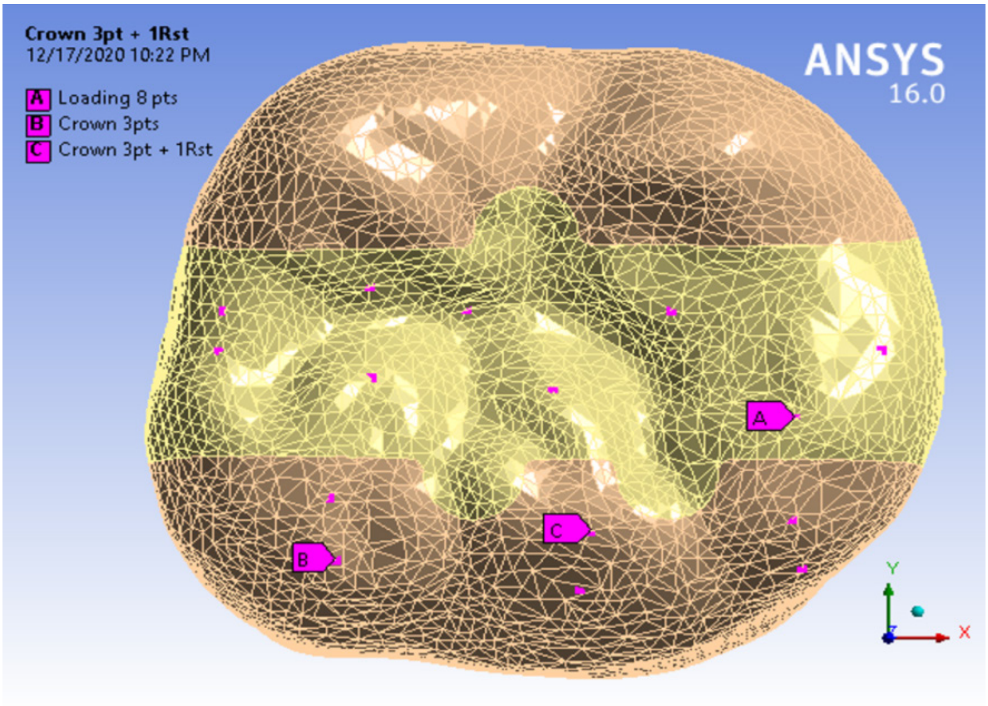

Figure 1. Loading points

6. Obtaining the data of resultant stresses

The resultant Von Mises stresses and Total deformations were calculated under both loading conditions and distributions as; maximal resultant values. Data analysis was performed in several steps. Initially, descriptive statistics for each group results. One-way ANOVA followed by pairwise Tukey's post-hoc tests were performed to detect significance between subgroups. Student t-test was done between paired groups. Two-way ANOVA was done to show the effect of each variable (main group and subgroup). Statistical analysis was performed using Graph-Pad InStat statistics software for Windows (www.graphpad.com). P values ≤0.05 are statistically significant in all tests. HP Z820, with Dual Intel Xeon E5-2660, 2.2 GHz processors, 64GB RAM .

Results

The distribution and magnitude of Von Mises stresses and Total deformation in each component of the model were calculated. In the present study Table 4 & Figure (3,5) revealed that an equivalent value of maximum Von Mises stress at 11- degree (234.7), at 45 -degree (299.8) and equivalent value of total deformation at 11- degree (0.0173), at 45 -degree (0.0526) were recorded on the final restoration of the two models. Also, there was a positive correlation between increase in the oblique angle incidence from the long axis of the tooth from (11º to 45º) and the stress received by the restorations.

The result of the present study Table 4 & Figure (7,9) revealed that both (CMR) materials showed nearly the same Total deformation at 11-degree (0.0109) and at 45-degree (0.0338), while flowable composite received less Von Mises stresses at 11-degree (4.7) and at 45-degree (5) than Riva at 11-degree (6.5) and at 45-degree (7.1) by about 40% in the model II.

Regardless of the difference in the oblique angle incidence from (11º to 45º) or the type of the material used for cervical marginal relocation material there was no significant difference in the stress distribution (finite element analysis) between the two models where the (CMR) technique was used or not.

The Von Mises stresses and Total deformation results of the six runs applied on final restorative material & (CMR) materials for (FEA) on the two models were illustrated in the Table 2 and Figures (2 - 9).

Table 2. The Von Mises and Total deformation of the six runs on the two models.

Runs	Von Mises	Total deformation
1- Model I –Ob 11º zenit	234,7	0,0173
2- Model I -Ob 45º zenit	299,8	0,0526
3- Model II – Ob 11º Dyract	4,7	0,0109
4- Model II – Ob 45º Dyract	5,0	0,0338
5- Model II – Ob 11º Riva	6,5	0,0109
6- Model II – Ob 45º Riva	7,1	0,0337

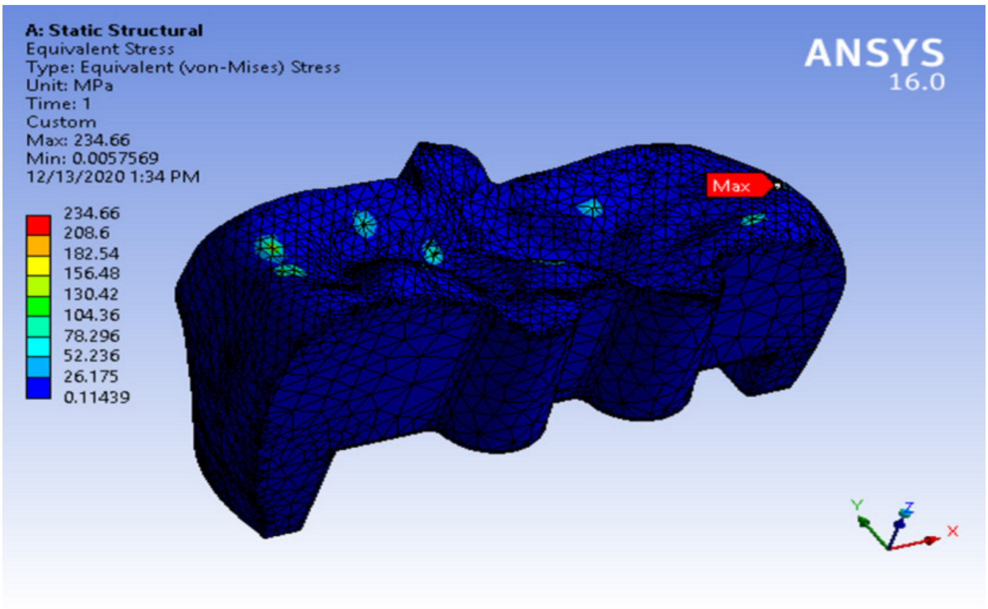

Figure 2. Model II (final restoration) Von Mises stress under oblique load at 11º from vertical axis

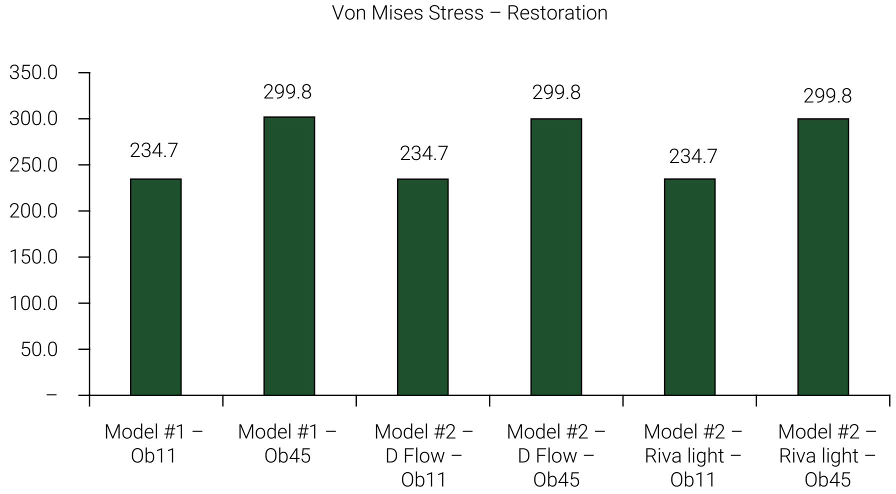

Figure 3. Column chart showing comparison of Von Mises of final restoration between the two models.

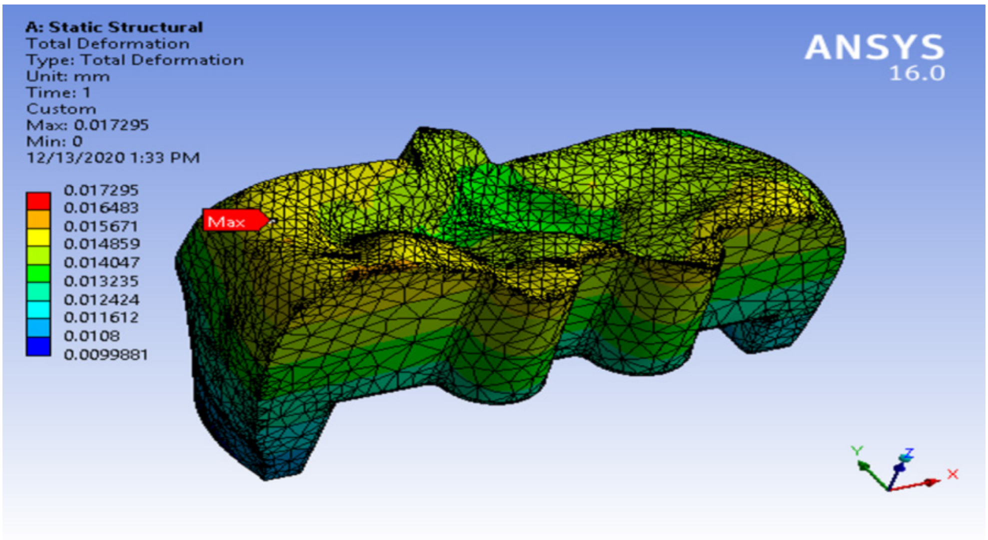

Figure 4. Model II (final restoration) Total deformation under oblique load at 11º from vertical axis

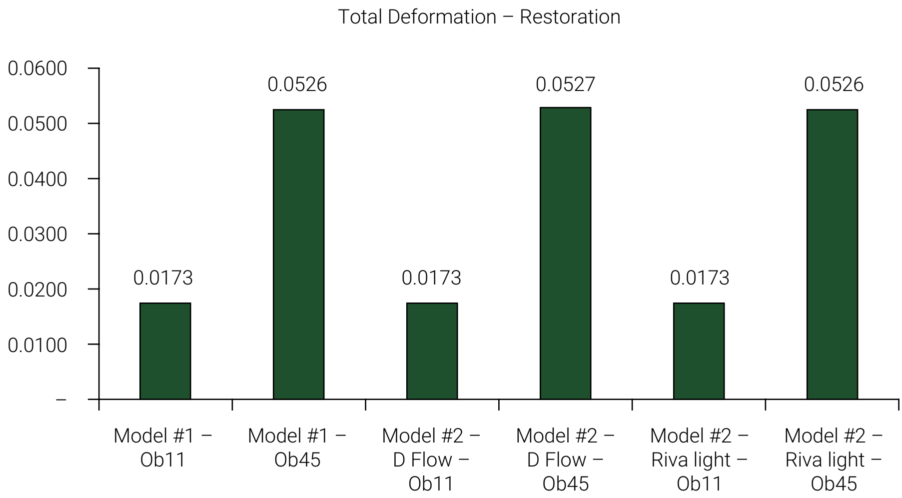

Figure 5. Column chart showing comparison of Total deformation of final restoration of the two models.

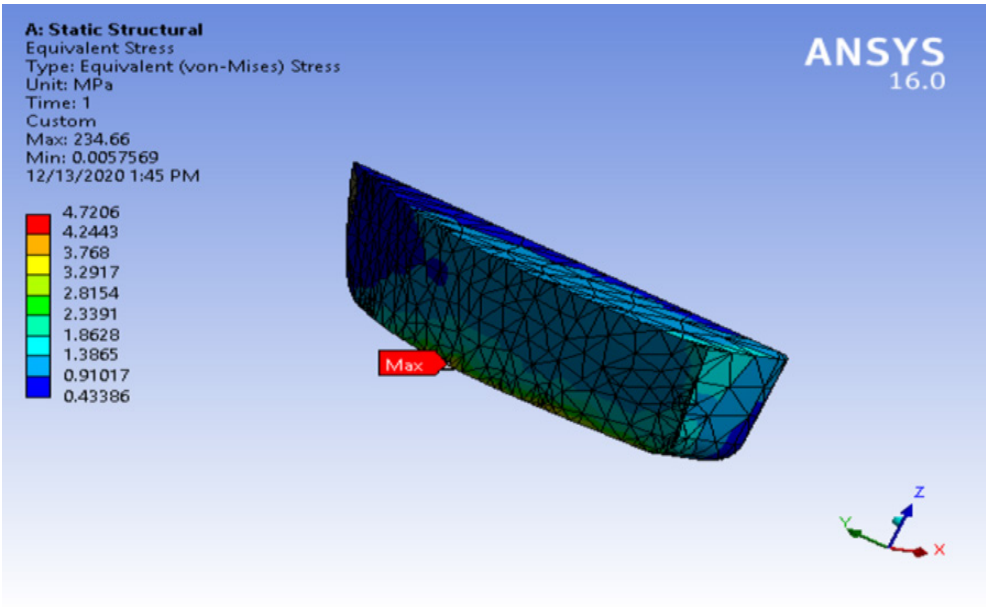

Figure 6. Model II (flowable resin relocation material) maximum Von Mises stress under oblique load at 11º from vertical axis

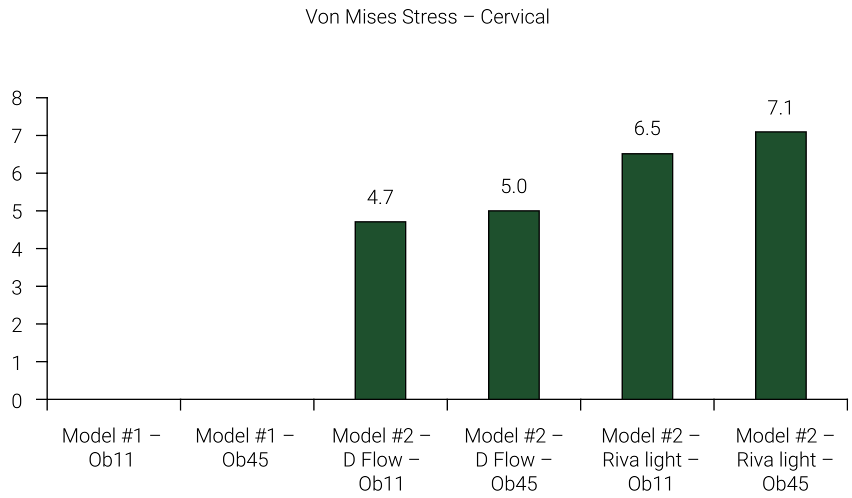

Figure 7. Column chart showing comparison of Von Mises of (CMR) materials in model II.

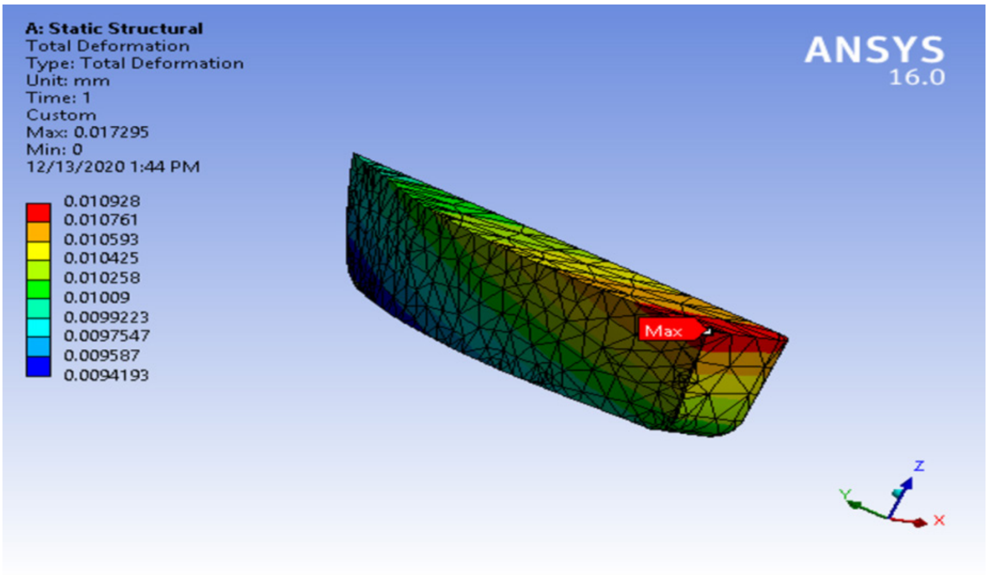

Figure 8. Model II (flowable resin relocation material) maximum Total deformation under oblique load at 11° from vertical axis

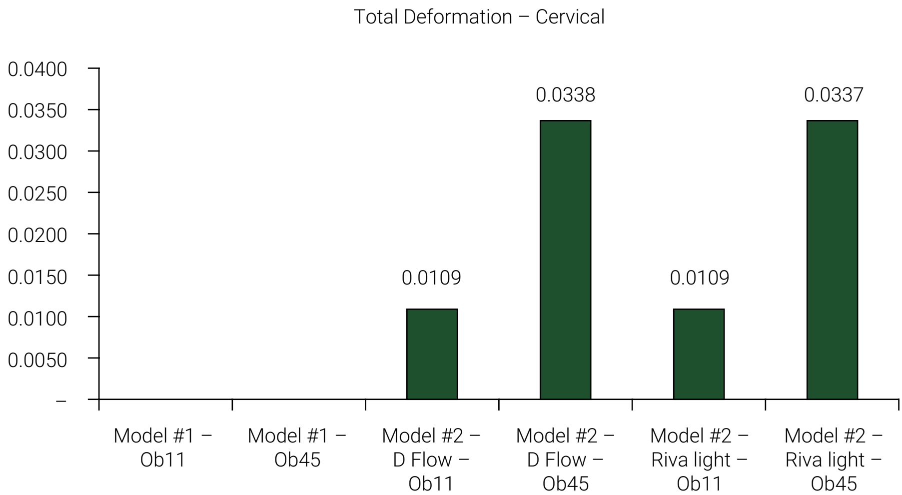

Figure 9. Column chart showing comparison of Total deformation of (CMR) materials in model II.

Discussion

(FEA) has been widely employed as an effective tool to evaluate the stress-strain distribution. It could evaluate the biomechanical characteristics of both the restored teeth and the dental restorative system. Further, the results carry significant clinical implications regarding the ability to withstand the masticatory forces in the oral cavity[11].

(FEA) values are divided as Von Mises stress, maximum principle stress (tensile stress), minimum principle stress (compressive stress), and shear stress. However, in most finite element studies presented in the literature, The von Mises criterion is a formula for combining three principal stresses into an equivalent stress, which is then compared to the yield stress of the material. If the "von Mises stress exceeds the yield stress, then the material is at the failure condition[9,10].

The 100 N load used in this study was chosen as the average chewing force, which is supposed to be one third of the maximum biting force. A restoration must resist natural forces that occur in the mouth[14-16]. A 45-degree angle to the long axis of the tooth was chosen to match the lateral the force (eccentric force) applied on the teeth during mastication[12,17-20] while an 11-degree angle to the long axis of the tooth was chosen to match the applied perpendicular force (centric force) on the teeth (90 degrees) during mastication[10].

Null hypothesis that the (CMR) has an adverse effect on stress distribution (FEA) on restored teeth was rejected because in this study (CMR) by resin glass ionomer or flowable composite resin in combination with nanoceramic composite improved the biomechanical behavior of MOD cavities extended below (CEJ).

The present study revealed that an increasing in the total deformation and Von Mises stresses applied on the final restoration under both models by increasing oblique angle from (11^0 to 45^0); this was in agreement with Rodrigues[10] (2016) who observed that the loads applied with a 45-degree angle incidence causes more stress accumulation on the final restoration than the load applied with an 11-degree angle incidence.

In the present study, an equivalent Von Mises stress and total deformation on the final restoration of the two models can be explained by the ability of the two (CMR) materials in the model II to support the deformations and stresses excreted on final restoration as in model I; this may be dependent on the fact that the elastic modulus of restorative materials plays an essential role in stress absorption and load transmission[21]. Hence, (CMR) could work as an "absorber," in which an intermediate layer of material with low elastic modulus reduces stress concentrations in the restoration and tooth structure[22]. Such findings corroborate those found by other authors[10,23-25] who found that there was no significant difference in the stress distribution between the two models, CMR was not negative for biomechanical behaviors and the use of glass ionomer cement or flowable composite resin in combination with a bulk-fill composite improved the biomechanical behavior of deep class II MO cavities. However, diverging from the findings of Ausiello et al.[26] (2017) who found that the direct resin-based composite materials applied in multilayer techniques to large class II cavities produced adverse FEA stress distributions.

In our study (CMR) materials showed nearly the same deformation at (11^{0},45^{0}), while flowable composite received less stress than Riva at (11^{0},45^{0}).This finding may be correlated to the material elasticity modulus; using restoration material with high elasticity received higher stress without differences in deformation so Riva absorbed more stresses than Dynamic Flow due to (Dynamic flow) lower in modulus of elasticity (5.3) than Riva (10.8) 15,29(2003). Such findings corroborate those found by other authors[8,27] who showed that a restorative material with appropriate elasticity module was able to absorb more stress.

In the current study, regardless the difference in the oblique angle incidence from (11º to 45º) or the type of the material used for (CMR) material there was no significant difference in the (FEA) between the two models where the (CMR) technique was used or not; this may be attributed to the (CMR) technique reduce the gingival extension of the restoration, placing it in a more coronal position, which may have reduced the lever arm and consequently the restoration deflexion[28]. Also, the base under the resin composite restoration might have acted as a tampon layer reducing the effects of stress concentration and the modulus of elasticity of Dynamic flow is close to dentin[28]. This finding was in agreement with Rodrigues[10] (2016) who observed that there was no significant difference in the stress distribution between the two models regardless the difference in the oblique angle incidence from (11º to 45º) or the type of the material used for (CMR) material.

A limitation of the present research is that several assumptions were made during designing of the models since the stress distribution pattern directly depends on the model design and the materials' properties assigned to each layer of the model, any inaccuracy may be directly reflected in the results. Also, the magnitude and direction of the maximum bite force and masticatory bite force considered in this study are averaged values and may not match the in vivo conditions accurately. In addition, this study does not simulate the ideal structure of the tooth. Further study is needed to allow the definition of the (Enamel, Dentin, Periodontal ligament & Cementum) in the model to mimic all dental structure related to the influence of (CMR) on (FEA).

In conclusion, within the limitations of the present study, the following conclusions were drawn: (CMR) technique seems to be biomechanically beneficial with high eccentric applied stress, (CMR) by resin glass ionomer or flowable composite resin in combination with nanoceramic composite improved the biomechanical behavior of MOD cavities extended below (CEJ), (CMR) with high modulus elasticity material like (Riva) exhibits a more uniform stress distribution.

Clinical significance

(CMR) does not impair biomechanical behavior.

Acknowledgments

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors have no conflicts of interest to declare.

Data Availability

Datasets related to this article will be available upon request to the corresponding author.

Author Contribution

- Nabil al Aggan: Methodology, validation, investigation, data curation, writing – original draft preparation and resources.
- Sameh Nabih: Conceptualization, methodology, investigation, writing – review and editing.
- Abd Allah Ahmed Abd Al Hady: Validation, investigation, writing – review, and editing.

All authors actively participated in the manuscript's findings and revised and approved the final version of the manuscript.

Reference

1. Da Rosa Rodolpho PA, Cenci MS, Donassollo TA, Loguercio AD, Demarco FF. A clinical evaluation of posterior composite restorations: 17-year findings. J Dent.2006 Aug;34(7):427-35. doi: 10.1016/j.jdent.2005.09.006.
2. Opdam NJ, van de Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, et al. Longevity of posterior composite restorations: a systematic review and meta-analysis. J Dent Res. 2014 Oct;93(10):943-9. doi: 10.1177/0022034514544217.
3. Juloski J, KÖken S, Ferrari M. No correlation between two methodological approaches applied to evaluate cervical margin relocation. Dent Mater J. 2020 Aug;39(4):624-32. doi: 10.4012/dmj.2018-410.

4. Magne P, Spreafico R. Deep margin elevation: a paradigm shift. Am J Esthet Dent. 2012;2(2):86-96 . Corpus ID: 130524661.

5. Frese C, Wolff D, Staehle HJ. Proximal box elevation with resin composite and the dogma of biological width: clinical R2-technique and critical review. Oper Dent. 2014 Jan-Feb;39(1):22-31. doi: 10.2341/13-052-T.

6. Venuti P, Eclano M, Avellino, Italy. Rethinking deep marginal extension. Int. Jo. Cosm. Dent, 2018; 7(1):26-32.

7. Kielbassa AM, Philipp F. Restoring proximal cavities of molars using the proximal box elevation technique: Systematic review and report of a case. Quintessence Int. 2015 Oct;46(9):751-64. doi: 10.3290/j.qi.a34459.

8. Sengul F, Gurbuz T, Sengul S. Finite element analysis of different restorative materials in primary teeth restorations. Eur J Paediatr Dent. 2014 Sep;15(3):317-22. PMID: 25306152.

9. Asmussen E, Peutzfeldt A. Class I and Class II restorations of resin composite: an FE analysis of the influence of modulus of elasticity on stresses generated by occlusal loading. Dent Mater. 2008 May;24(5):600-5. doi: 10.1016/j.dental.2007.06.019.

10. Rodrigues F. Ceramic Onlay: Influence of the Deep Margin Elevation Technique on Stress Distribution—A Finite Element Analysis [master's thesis]. Coimbra, Portugal: University of Coimbra; 2016.

11. Srirekha A, Bashetty K. Infinite to finite: an overview of finite element analysis. Indian J Dent Res. 2010 Jul-Sep;21(3):425-32. doi: 10.4103/0970-9290.70813.

12. Bandela V and Kanaparthi S. Finite element analysis and Its applications in dentistry. Intech Open. 2020 Nov 11;1-24. doi: 10.5772/intechopen.94064.

13. D'souza KM, Aras MA. Three-dimensional finite element analysis of the stress distribution pattern in a mandibular first molar tooth restored with five different restorative materials. J Indian Prosthodont Soc. 2017 Jan-Mar;17(1):53-60. doi: 10.4103/0972-4052.197938.

14. Joshi S, Mukherjee A, Kheur M, Mehta A. Mechanical performance of endodontically treated teeth. Finite Elements Anal Design. 2001;37(8):587-601. doi: 10.1016/S0168-874X(00)00059-7.

15. Okamoto K, Ino T, Iwase N, Shimizu E, Suzuki M, Satoh G, et al. Three-dimensional finite element analysis of stress distribution in composite resin cores with fiber posts of varying diameters. Dent Mater J. 2008 Jan;27(1):49-55. doi: 10.4012/dmj.27.49.

16. Amarante MV, Pereira MVS, Darwish FAI, Camardo AF. Virtual analysis of stresses in human teeth restored with esthetic posts. Mater Res. 2008;11(4):459-63. doi: 10.1590/S1516-14392008000400014.

17. Zhong Q, Huang Y, Zhang Y, Song Y, Wu Y, Qu F, et al. Finite element analysis of maxillary first molar with a 4-wall defect and 1.5-mm-high ferrule restored with fiber-reinforced composite resin posts and resin core: the number and placement of the posts. J Prosthet Dent. 2022 Mar:S0022-3913(22)00077-4. doi: 10.1016/j.prosdent.2022.01.029.

18. Zhu J, Luo D, Rong Q, Wang X. Effect of biomimetic material on stress distribution in mandibular molars restored with inlays: a three-dimensional finite element analysis. PeerJ. 2019 Sep;7:e7694. doi: 10.7717/peerj.7694.

19. Kumar P, Rao RN. Three-dimensional finite element analysis of stress distribution in a tooth restored with metal and fiber posts of varying diameters: an in-vitro study. J Conserv Dent. 2015 Mar-Apr;18(2):100-4. doi: 10.4103/0972-0707.153061.

20. Agarwal SK, Mittal R, Singhal R, Hasan S, Chaukiyal K. Stress evaluation of maxillary central incisor restored with different post materials: a finite element analysis. J Clin Adv Dent. 2020;4:22-27. doi: 10.29328/journal.jcad.1001020.

21. Tribst JPM, Dal Piva AMO, Borges ALS, Araújo RM, da Silva JMF, Bottino MA, et al. Effect of different materials and undercut on the removal force and stress distribution in circumferential clasps during direct retainer action in removable partial dentures. Dent Mater. 2020 Feb;36(2):179-86. doi: 10.1016/j.dental.2019.11.022.

22. Friedl KH, Schmalz G, Hiller KA, Mortazavi F. Marginal adaptation of composite restorations versus hybrid ionomer/com- posite sandwich restorations. Oper Dent. 1997;22(1):21-9.

23. Ausiello P, Ciaramella S, De Benedictis A, Lanzotti A, Tribst JPM, et al. The use of different adhesive filling material and mass combinations to restore class II cavities under loading and shrinkage effects: a 3D-FEA. Comput Methods Biomech Biomed Engin. 2021 Apr;24(5):485-95. doi: 10.1080/10255842.2020.1836168.

24. Alp Ş, Gulec Alagoz L, Ulusoy N. Effect of Direct and Indirect Materials on Stress Distribution in Class II MOD Restorations: A 3D-Finite Element Analysis Study. Biomed Res Int. 2020 Dec;2020:7435054. doi: 10.1155/2020/7435054.

25. Grassi EDA, de Andrade GS, Tribst JPM, Machry RV, Valandro LF, Ramos NC, et al. Fatigue behavior and stress distribution of molars restored with MOD inlays with and without deep margin elevation. Clin Oral Investig. 2022 Mar;26(3):2513-26. doi: 10.1007/s00784-021-04219-6.

26. Ausiello P, Ciaramella S, Martorelli M, Lanzotti A, Gloria A, Watts DC. CAD-FE modeling and analysis of class II restorations incorporating resin-composite, glass ionomer and glass ceramic materials. Dent Mater. 2017 Dec;33(12):1456-65. doi: 10.1016/j.dental.2017.10.010.

27. Yaman SD, Sahin M, Aydin C. Finite element analysis of strength characteristics of various resin based restorative materials in Class V cavities. J Oral Rehabil. 2003 Jun;30(6):630-41. doi: 10.1046/j.1365-2842.2003.01028.x.

28. Vertolli TJ, Martinsen BD, Hanson CM, Howard RS, Kooistra S, Ye L. Effect of deep margin elevation on CAD/CAM-fabricated ceramic inlays. Oper Dent. 2020 Nov;45(6):608-17. doi: 10.2341/18-315-L.