EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

VOL. 69, 3081:3089, OCTOBER, 2023

PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360

CONSERVATIVE DENTISTRY AND ENDODONTICS

Submit Date : 18-06-2023 • Accept Date : 06-08-2023 • Available online: 20-10-2023 • DOI : 10.21608/EDJ.2023.218074.2606

EFFECT OF CAVITY OPTIMIZATION ON THE FRACTURE RESISTANCE OF INLAY-RESTORED MOLARS (AN IN-VITRO STUDY)

Fatma Adel Mohamed Ahmed* *and* Dena Safwat Mustafa**

ABSTRACT

Purpose: The goal of this study was to assess the effect of two different types of resin-based composites used for cervical margin relocation (CMR) on fracture resistance and mode of failure of ceramic MOD-inlay restorations.

Materials and Methods: Twenty-four MOD Class II cavities (3 mm in width and 2 mm in depth) were prepared in human first molars to receive indirect E-max CAD ceramic inlays; where mesially proximal boxes extend 2 mm below the cementoenamel junction (CEJ). Prepared cavities were allocated into three groups (n = 8) to perform the cervical margin relocation; Group I: inlay without CMR, Group II: restored with (SDR), Group III: restored with injectable composite. Thermocycling was performed at 5,000 cycles in water bath at (5-55 °C) in a standard thermocycling machine. Specimens were subjected to fracture resistance testing using the Universal Testing Machine. Data was statistically analyzed using One-way ANOVA followed by Tukey's post hoc test.

Results: There was a significant difference between different groups ($p<0.001$). The highest strength value was found in injectable composite samples (1760.88±240.05 N) while the lowest value was recorded by inlay without CMR (906.94±90.66 N).

Conclusion: High-strength injectable is the best base regarding enhancement to fracture resistance.

KEYWORDS: Biomimetic Approach - Proximal box elevation - MOD Inlays - Injectable Composites - Restoration Longevity - Cervical Margin Relocation

* Lecturer of Fixed Prosthodontics, Department of Fixed Prosthodontics, Faculty of Dentistry, Ain-Shams University
** Lecturer of Operative Dentistry, Department of Operative Dentistry, Faculty of Dentistry, Ain-Shams University

INTRODUCTION

The ultimate goal of restorative dentistry is preservation of tooth integrity as well as establishing restorative systems that are capable of serving the patient for their lifetime with superior esthetics and strength. During restoration, the intent is to imitate the natural multi-layered bio-complex in line with biomimetic dentistry and the concept of bio-emulation. Biomimetic restorative protocols aim to achieve this by removing defective tissue conservatively and restoring teeth with materials and techniques that provide both stress-reduction and adhesive bond maximization. Combined use of restorative materials and enhanced bonding systems with smart preparation design allows the tooth to function as one entity against functional forces. [1-4]

Extensive, complex cavities in posterior teeth remain a common finding in modern day practice.[5] Besides the need for preservation of remaining tissues and pulp protection, the build-up and restoration of normal occlusal contact and proximal contours is a tedious and time-consuming process. In many cases, indirect inlays are the preferred restorative approach as it offers a package of multiple advantages including high esthetic potential, reliable mechanical properties, relatively convenient time, favorable discoloration rate as well as low 2-body wear, compared to direct resin composite restorations. [6]

Nevertheless, extensive cavities seldom present themselves without an added challenge related to preparation depth approximating the gingival tissues. Successful placement of the final restoration without salivary or blood contamination, necessary isolation as well as impression taking, cementation finishing and polishing for the cervical area can be extremely arduous even for a competent practitioner. Deep margins possess harder, less-friendly bonding substrate as enamel thins down and progressively disappears merging towards root cementum. This may jeopardize marginal integrity as well as adaptation with higher likelihood for microleakage and accelerated deterioration. [7, 8, 9, 10] Even more, harming soft tissues, subsequent gingival inflammation and biological width violation are unfortunate, yet highly likely. [11] Resorting to the surgical alternative of crown lengthening can solve this, yet remains an additional more complicated, invasive step. [12]

To navigate the complexity of sub-gingival restorations, an experienced clinician can leverage the best of both worlds by combining direct and indirect materials for optimum results. [13] Cervical margin relocation (CMR), or proximal box elevation (PBE) as the name implies, is the procedure used to relocate preparation margins that are deep and sub-gingival to a more favorable and accessible supra-gingival position. [14] Nowadays, it too has become a custom procedure to apply direct base beneath indirect adhesive restorations with the prospect for it to deliver immediate dentin sealing, facilitate impressions, and enhance the final restoration marginal seal and adaptation. [8, 15] Indirect CAD/CAM restorations following CMR were reported to increase the marginal and structural integrity. [16]

It is well established that deep caries, extensive cavities, and endodontic treatment ultimately reduce the fracture resistance of teeth. In spite of this, investigations involving fracture resistance of inlay-restored molars combined with CMR are in short supply. A large body of research exists dedicated to endodontically treated teeth. Many studies including finite element analyses have explored preparation design, use of reinforced composites within pulp chambers, and the final restorative material ranging from conventional composites to hybrid ceramics. In many instances, this has led to clinical recommendations to resort to larger cuspal coverage as with endocrowns and onlays compared to inlays. [17] or no difference at all with/without CMR regardless the type of restorative material used. [18, 19, 20]

Thus far, clinicians lack a clear evidence-based recommendation with regards the effect of cervical margin relocation procedure on fracture resistance of ceramic inlay restored teeth that have not received endodontic treatment. [21] Furthermore, owing to the ongoing advancements in materials chemistry and properties, proximal boxes can be elevated using an extensive list of materials each with a proposed reward. [22] Therefore, it is worth investigating clinically available materials exhibiting jointly enhanced flow, strength and depth of cure.

Null hypothesis:

Cervical margin relocation with two different types of resin composite does not influence fracture resistance of the indirect ceramic inlays restoring MOD cavities.

AIM OF THE STUDY

The aim of this study is to evaluate the cervical margin relocation procedure regarding the following:

- Primary outcome: influence of two different types of resin-based composite used for cervical margin relocation.
- Secondary outcomes:
  - Fracture Resistance of MOD-inlay restoration
  - Mode of Failure: Repairable or catastrophic

MATERIALS AND METHODS

This study was approved by the Research Ethics Committee of Faculty of Dentistry, Ain Shams University, Cairo, Egypt (FDASU-REC) with approval number FDASU-Rec ER052337. A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between different groups regarding fracture resistance. By adopting an alpha (α) level of 0.05 (5%), a beta (β) level of 0.2 (i.e. power=80%), and an effect size (f) of (0.689) calculated based on the results of a previous study (23); the predicted sample size (n) was a total of (24) samples (8 per group). Sample size calculation was performed using G*Power version 3.1.9.7 [24].

Twenty-four human first molars were used in this study. Teeth were stored in 0.1% thymol solution until use. Teeth were cleaned from any soft tissue debris and checked for cracks or defects under magnification. Roots of selected teeth were subsequently vertically positioned in self-curing acrylic resin inside circular molds, and it was made so that the resin stops 3 mm below the CEJ.

Mesio-occlusal-distal (MOD) Class II cavities were prepared to receive the indirect ceramic inlays using a high-speed handpiece mounted into a parallelo-meter for standardization. Cavities were prepared under water coolant using blue-coded, 80μm-grit diamond burs. Finishing was performed using white-coded, 25μm grit diamond burs (Intensive Inlay Set, Intensiv, Grancia, Switzerland). The final cavity dimensions were verified using a digital caliber as 3 mm in width and 2 mm in depth, and with proximal boxes extending 2 mm below the CEJ mesially and 2 mm above the CEJ distally.

Then, the prepared cavities were randomly distributed into three groups (n = 8) to perform the cervical margin relocation. Group I served as a control group where no cervical margin relocation was performed prior to receiving final inlay restoration. Group II, mesial boxes received a single increment of 4mm thickness, cured in bulk with (SDR Bulk-fill, flowable composite, Dentsply, Sirona). Finally, Group III, mesial boxes received highly filled, G-ænial Universal Injectable light-cured restorative composite (GC Corporation, Tokyo, Japan) applied in two 2 mm increments.

To insert the flowable materials, circumferential matrices around each tooth were placed in such a way to eliminate any resin composite overhangs at the margins. To ensure accurately filling of the mesial proximal box to the needed height, a mark was made on the inner side of each matrix using with a thin, permanent marker. Afterwards, the designated elevating material for each group was used.

For control Group I, no restorative procedure precedes the indirect inlays fabrication. While for both Groups II and III, selective enamel etching was performed for 15 seconds, rinsed for equal time, and gently dried. Prime and bond (Dentsply Sirona, NC, USA) was applied following manufacturer instructions for 20 seconds, air blown for 10 seconds, then light cured. Then, mesial proximal box received (CMR) with two consecutive 2mm increments of highly filled injectable composite, and with one 4-mm thick increment of bulk-fill flowable material for group II and III respectively. All materials used in this study were cured strictly according to the manufacturer's instructions.

Teeth were scanned using CEREC Omnicam (Dentsply Sirona). After that, e max CAD (Ivoclar, Schaan, Liechtenstein) inlays were designed with CEREC 4.4 CAD–CAM software and milled using an inLab MCXL4 milling machine (Dentsply Sirona). For the surface treatment of the inlays, manufacturer instructions were followed. For tooth substrate, selective enamel etching was performed for 15 seconds, rinsing for equal time, then followed by drying. A dual-cured self-adhesive resin cement (Calibra Universal, Dentsply Sirona) was used and applied in cavities, after which the inlays were carefully positioned and seated followed by tack curing. Any excess luting agent was removed using a scaler followed by an additional time of 40 seconds each to ensure proper cure and polymerization. Specimens were stored for 24 hours in distilled water at room temperature. Afterwards, thermocycling was then performed at 5,000 cycles in the same water bath at (5–55°C) in a standard thermocycling machine (Thermocycler, Robota, Alexandria, Egypt), for 30 seconds/cycle with a 5-second interval between every 2 baths.

After thermocycling, specimens were subjected to fracture resistance testing. Test was performed using the Universal Testing Machine (Lloyd LR5K Instruments/Ametek, USA) at Biomaterials Testing Unit, Faculty of Dentistry, Ain Shams University. Load was applied axially onto occlusal surfaces of molars at a crosshead speed of 1mm/min until fracture and values were recorded. Load was applied using a static compression force onto the tooth by a 5 mm steel ball/sphere. The force at which the tooth fractures was recorded in Newton as the fracture resistance.

Fracture Analysis

The fracture analysis was performed using digital photography (Canon EOS 800D Digital SLR, Taiwan). Mode of fracture of the specimens was evaluated by two observers and assigned to the following categories based on the pattern of failure. Fractures were divided into two categories: favorable failures where repairable fractures were observed above the cemento-enamel junction (CEJ), while unfavorable failures were catastrophic irreparable fractures below the CEJ. Additionally, failure types were further observed as enamel fracture, ceramic fracture, ceramic-enamel fracture, ceramic-dentin fracture or crown-root fracture. The numbers of each fracture were recorded. [25]

RESULTS

Data was collected, tabulated, and statistically analyzed.

Statistical analysis:

Numerical data was represented as mean and standard deviation (SD) values. Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Data showed parametric distribution and variance homogeneity and was analyzed using one-way ANOVA followed by Tukey's post hoc test. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.0 for Windows [26].

Results of intergroup comparisons are presented in Table (1). Results showed that there was a significant difference between different groups ($p<0.001$). The highest strength value was found in high-strength injectable composite samples (1760.88±240.05 N), followed by SDR bulk-fill flowable composite (1239.41±181.76 N), while the lowest value was found in the control group receiving no cervical margin relocation (906.94±90.66 N). All post-hoc pairwise comparisons were statistically significant ($p<0.001$).

Upon examination of specimens following fracture testing, Group I control as well as Group II SDR Bulk-fill flowable, 70% of fracture was catastrophic irreparable fracture evident in both tooth structure and inlay (crown-root fracture). 30% of fracture was favorable or repairable fractures above the CEJ and detected as (ceramic-enamel fracture). Conversely, Group III Injectable, 90 % of the fracture was recorded in inlay (ceramic) with minor enamel chipping or minor enamel chipping only. The remaining 10% in Group III was catastrophic irreparable fracture, evident in both tooth structure and inlay (crown-root fracture). (Figure.1)

TABLE (1) Intergroup comparisons

Fracture resistance (N) (Mean±SD)			f-value	p-value
Control	Bulk-fill flowable composite	Injectable composite		
906.94±90.66^{C}	1239.41±181.76^{B}	1760.88±240.05^{A}	44.97	<0.001*

Means with different superscript letters within the same horizontal row are significantly different *significant (p<0.05)

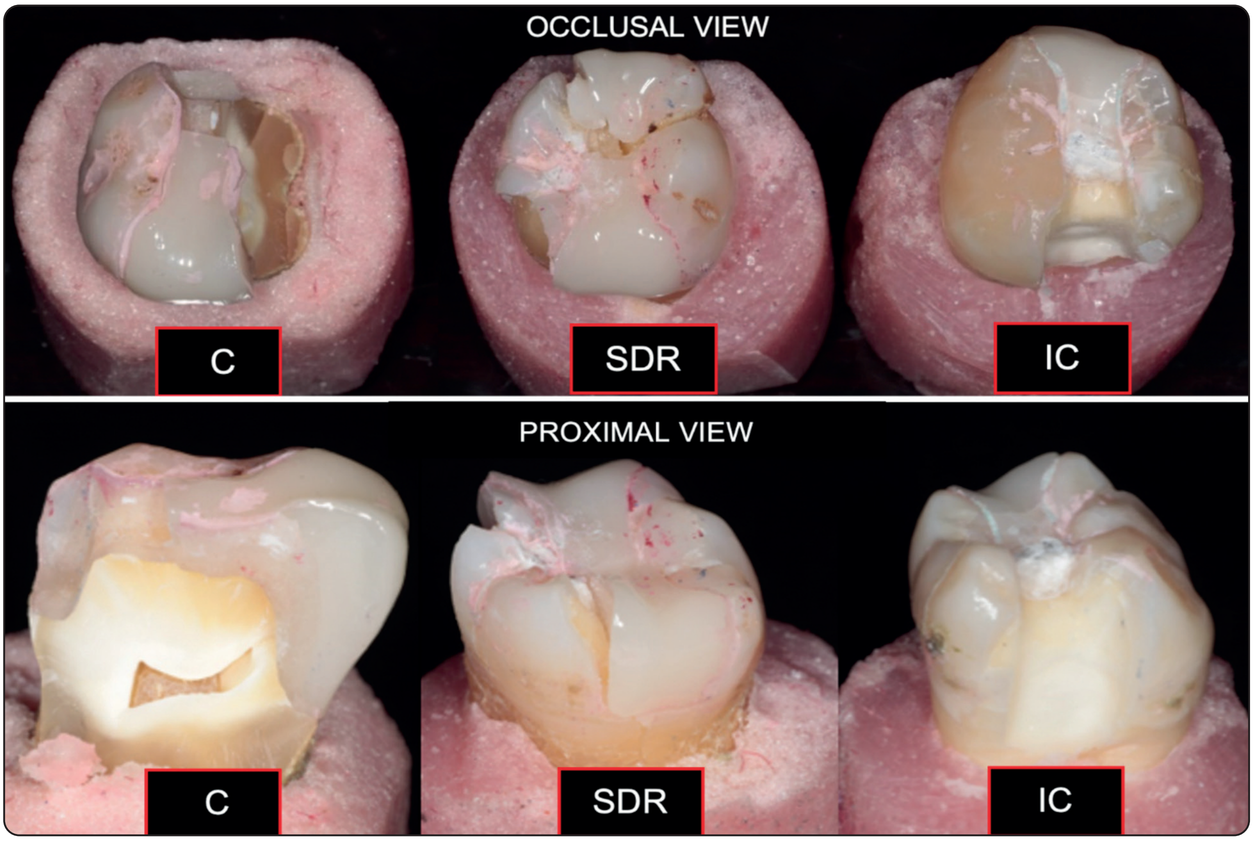

Fig. (1): Digital pictures of representative specimens with most prevalent fracture types for experimental groups: Group I Control (C) - Group II Bulk Fill Flowable (SDR) –Group III Injectable Composite (IC); Occlusal view and Proximal View

DISCUSSION

Restoring extensive cavities with indirect, ceramic inlays has gained popularity over time owing to the overall improvement in adhesive technology and resin cements.[23] Alongside, with the constant innovations in materials, ceramic inlays specifically have shown to be more successful at safeguarding the residual dental substrate, by more convenient stress distribution within enamel-inlay bonded interfaces.[27,28] Implementing CMR where indicated further enhances the immediate restorative outcome as well as the its continuing serviceability. [29]

The best material for CMR with indirect ceramic inlays restoring MOD cavities with regards to fracture resistance is still unclear. The materials used in this study were selected after considering results from past studies and a potential relationship between fracture resistance and marginal integrity. According to Krifka et al., improved marginal adaptation may help prevent long-term loading-related tooth fracture.[30] Regular flowable composites yield higher marginal seal and internal adaptation compared to nanohybrids. However, their composition makes them more susceptible to degradation during service. Thus a more highly filled alternative may promise strength and enhanced durability. [31]

Many materials are gaining market share and popularity on account of simplified application, quickness and enhanced flow. Our study investigated two different flowable materials whose application procedure is simple, and therefore fitting for clinical situations at high risk of moisture contamination. SDR® Bulk Fill Flowable (Dentsply, Sirona) has been idolized as a game-changer for deep Class II restorations. It has been praised for tolerating cure in 4mm increments (bulk fill), and impressive clinical durability claimed to be comparable to that of traditional techniques, only faster. Even more, SDR™ promised excellent marginal integrity and reduced microleakage owing to superior flow and reduced shrinkage stress. [23] Likewise, G-ænial Universal Injectable composite was used allowing for the application of two consecutive, thin layers of flowable material.

For the sake of this study, using two different flowable materials in two different increment thicknesses and application techniques highlighted the potential effects of unalike polymerization shrinkage that may occur even in relatively small quantity of CMR material. Furthermore, incrementation was endorsed as a pre-requisite to marginal integrity and fewer gaps when using condensable composites for CMR. From a clinical perspective, it may be much more user-friendly to independently bond one or two increments of resin composite to the proximal box floor compared to the full cementation process of a complete inlay with higher risk of contamination. [32]

Elastic modulus and surface hardness of restorative materials are great predictors to the clinical performance. Harmonizing material elastic moduli with tooth hard tissues facilitates the uniform sharing of stresses during the functional masticatory load. The more the discrepancy across the tooth-restoration interface the higher the probability of fracture of remaining tooth structure. [2] Dietschi stated that flowable composites when placed as an intermediate layer act as stress-absorbing layer during functional loading. The stress-mediating ability of flowable composite is directly proportional to the thickness and modulus of the material. [29, 33]

Higher fracture resistance values recorded by Group III injectable composite (IC) may be attributed to the material exhibiting higher stiffness, forbidding detrimental flexing of the tooth. This can also be supported by most frequent mode of failure being far from tooth, with minor enamel chipping only. [27] In contrast, yet in alignment with Yamanel, the results of this study showed the lower elastic modulus material to cause more stress transferral to tooth structures. [28] This may also explain why SDR bulkfill flowable group demonstrated fractures involving ceramic and dentin. This coincides with the fact that injectable composite has filler load 50 volume %, while SDR has filler load at 44 volume %.[34]

Ilgenstein et al found that regardless of the type of material, CMR had no effect on fracture resistance of CAD/CAM ceramic and composite onlays.[35] These results share several similarities with the findings of Grubbs et al, who demonstrated no statistical significant difference by CMR on fracture resistance, even when using glass ionomers, RMGICs, composites, and bulk-fill composites. [36] However, Zhang H. et al., revealed that fracture resistance of teeth restored by ceramic indirect restorations was increased by CMR but without significant difference in the type of restorative material used in CMR [18].

Lower values recorded by Group II SDR Bulk fill flowable may be attributed to the relatively higher polymerization shrinkage which can affect margin condition. According to Jang et al, bulk fill flowable composites in 4mm increments shrunk back more than traditional composites and even bulk-fill non-flowable composites.[34] Total shrinkage of the composite as CMR material should be harmless due to its passably modest amount. Nonetheless, the multifaceted occurrence of loading of the highly stiff ceramic, onto a substantially different elastic modulus, with an abrupt transition zone between resin composite applied in the first session and freshly applied luting resin may jeopardize the longevity of this tooth restoration complex. [37] It is worth noting that the proximal extensions of the indirect restorations with CMR were relatively short and this may be responsible for the higher fracture resistance values compared to control group with no CMR. This makes it easier for the restoration to fully seat along the preparation margin. [38] Better adaptation may help prevent loading-induced tooth fracture. [30]

Finally, the forces recorded in this study necessary to fracture inlays with or without CMR, by far exceeded the standard physiological occluding forces that can be expected in clinical context. Also, and within the limitations of this study, CMR may alleviate the effect of fracture or increase serviceability of the tooth-restoration complex. [25] In light of that and from a bio-mechanical perspective, when encountering high or involuntary forces as with Bruxer patients, it may be more in accordance to the biomimetic approach to proceed with inlays in conjunction with injectable composites, without the injudicious use of full coverage or excessive tooth preparation.

CONCLUSION

Within the limitations of this study, the following could be concluded.

- Cervical margin relocation has a positive effect on fracture resistance of ceramic MOD-inlay restorations.
- High-strength injectable is the best base regarding enhancement to fracture resistance. Higher filler content may impart properties that make a material more suitable for cervical margin relocation.

Limitations

Human molars used in this study may have had slightly different dimensions, standardized preparations were carried out to ensure that the indirect restorations were all the same size. Therefore, slight variation in volume of remaining tooth structure supporting the indirect restorations may account for minor variation. In order to lessen the impact of both variables on the findings of the research, the samples were randomly allocated into the experimental groups.

REFERENCES

1. Bazos P, Magne P. Bio-emulation: biomimetically emulating nature utilizing a histo-anatomic approach; structural analysis. Eur J Esthet Dent. 2011;6(1):8–19].

2. Zafar MS, Amin F, Fareed MA, Ghabbani H, Riaz S, Khurshid Z, Kumar N. Biomimetic Aspects of Restorative Dentistry Biomaterials. Biomimetics (Basel). 2020 Jul 15;5(3):34. doi: 10.3390/biomimetics5030034.

3. Goswami S. Biomimetic dentistry. J Oral Res Rev. 2018;10(1):28–32]. a. [9 Burke FJ. From extension for prevention to prevention of extension: (minimal intervention dentistry). Dent Update. 2003;30(9):492–8.].

4. Singer L, Fouda A, Bourauel C. Biomimetic approaches and materials in restorative and regenerative dentistry: review article. BMC Oral Health. 2023 Feb 16;23(1):105. doi: 10.1186/s12903-023-02808-3. PMID: 36797710; PMCID: PMC9936671.

5. Vetromilla BM, Opdam NJ, Leida FL, Sarkis-Onofre R, Demarco FF, van der Loo MPJ, Cenci MS, Pereira-Cenci T. Treatment options for large posterior restorations: a systematic review and network meta-analysis. J Am Dent Assoc. 2020 Aug;151(8):614-624.e18. doi: 10.1016/j.adaj.2020.05.006. PMID: 32718491.

6. Fernando Zarone, Marco Ferrari, Francesco Guido Mangano, Renato Leone, Roberto Sorrentino, "“Digitally Oriented Materials”: Focus on Lithium Disilicate Ceramics", International Journal of Dentistry, vol. 2016, Article ID 9840594, 10 pages, 2016. https://doi.org/10.1155/2016/9840594 [44].

7. Juloski J., Köken S., Ferrari M. Cervical Margin Relocation in Indirect Adhesive Restorations: A Literature Review. J. Prosthodont. Res. 2018;62:273-280. doi: 10.1016/j.jpor.2017.09.005.

8. Kielbassa A.M., Philipp F. Restoring Proximal Cavities of Molars Using the Proximal Box Elevation Technique: Systematic Review and Report of a Case. Quintessence Int. 2015;46:751–764.

9. D'Arcangelo C., Vanini L., Casinelli M., Frascaria M., De Angelis F., Vadini M., D'Amario M. Adhesive Cementation of Indirect Composite Inlays and Onlays: A Literature Review. Compend. Contin. Educ. Dent. 2015;36:570–578.

10. Veneziani M. Adhesive Restorations in the Posterior Area with Subgingival Cervical Margins: New Classification and Differentiated Treatment Approach. Eur. J. Esthet. Dent. 2010;5:50–76.

11. Ferrari M., Koken S., Grandini S., Ferrari Cagidiaco E., Joda T., Discepoli N. Influence of Cervical Margin Relocation (CMR) on Periodontal Health: 12-Month Results of a Controlled Trial. J. Dent. 2018;69:70–76. doi: 10.1016/j.jdent.2017.10.008.

12. Sarfati A., Tirlet G. Deep Margin Elevation Versus Crown Lengthening: Biologic Width Revisited. Int. J. Esthet. Dent. 2018;13:334–356.

13. Magne P, Spreafico RC. Deep margin elevation: a paradigm shift. Am J Esthet Dent. 2012;2(2):86–96.

14. Dietschi, D.; Spreafico, R. Current Clinical Concepts for Adhesive Cementation of Tooth-Colored Posterior Restorations. Pract. Periodont. Aesthet. Dent. 1998, 10, 47–54.

15. Da Silva Gonçalves, D.; Cura, M.; Ceballos, L.; Fuentes, M. Influence of Proximal Box Elevation on Bond Strength of Composite Inlays. Clin. Oral. Investig. 2017, 21, 247–254.

16. Vertolli, T.J.; Martinsen, B.D.; Hanson, C.M.; Howard, R.S.; Kooistra, S.; Ye, L. Effect of Deep Margin Elevation on CAD/CAM Fabricated Ceramic Inlays. Oper. Dent. 2020, 45, 608–617.

17. Huda I, Pandey A, Kumar N, Sinha S, Kavita K, Raj R. Resistance against Fracture in Teeth Managed by Root Canal Treatment on Restoring with Onlays, Inlays, and Endocrowns: A Comparative Analysis. J Contemp Dent Pract. 2021 Jul 1;22(7):799-804. PMID: 34.

18. Zhang H, Li H, Cong Q, Zhang Z, Du A, Wang Y. Effect of proximal box elevation on fracture resistance and microleakage of premolars restored with ceramic endocrowns. PLoS One. 2021 May 26;16(5):e0252269. doi: 10.1371/journal.pone.0252269.

19. Aldakheel M, Aldosary K, Alnafissah S, Alaamer R, Alqahtani A, Almuhtab N. Deep Margin Elevation: Current Concepts and Clinical Considerations: A Review. Medicina (Kaunas). 2022 Oct 18;58(10):1482. doi: 10.3390/medicina58101482.

20. Samartzi TK, Papalexopoulos D, Ntovas P, Rahiotis C, Blatz MB. Deep Margin Elevation: A Literature Review. Dent J (Basel). 2022 Mar 14;10(3):48. doi: 10.3390/dj10030048.

21. Eggmann F, Ayub JM, Conejo J, Blatz MB. Deep margin elevation-Present status and future directions. J Esthet Restor Dent. 2023 Jan;35(1):26-47. doi: 10.1111/jerd.13008.

22. Ismail HS, Ali AI, Mehesen RE, Juloski J, Garcia-Godoy F, Mahmoud SH. Deep proximal margin rebuilding with

direct esthetic restorations: a systematic review of marginal adaptation and bond strength. Restor Dent Endod. 2022 Mar 4;47(2):e15. doi: 10.5395/rde.2022.47.e15.

23. Barakat, Ola, and Noha Mohammed. "Effect Of Different Base Materials On The Micro Leakage And Fracture Resistance Of Recent Ceramic Inlay Restorations." Egyptian Dental Journal 65.4-October (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics) (2019): 3805-3816.

24. Faul, Franz, et al. "G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences." Behavior research methods 39.2 (2007): 175-191.

25. Bresser RA, van de Geer L, Gerdolle D, Schepke U, Cune MS, Gresnigt MMM. Influence of Deep Margin Elevation and preparation design on the fracture strength of indirectly restored molars. J Mech Behav Biomed Mater. 2020 Oct;110:103950. doi:10.1016/j.jmbbm.2020.103950.

26. R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

27. Yu P, Xiong Y, Zhao P, et al. On the wear behavior and damage mechanism of bonded interface: Ceramic vs resin composite inlays. Journal of the Mechanical Behavior of Biomedical Materials. 2020 Jan;101:103430. DOI: 10.1016/j.jmbbm.2019.103430.

28. Yamanel K, Caglar A, Gülsahi K, Ozden UA. Effects of different ceramic and composite materials on stress distribution in inlay and onlay cavities: 3-D finite element analysis. Dent Mater J. 2009 Nov;28(6):661-70. doi: 10.4012/dmj.28.661. PMID: 20019416.

29. Dietschi, D.; Spreafico, R. Evidence-Based Concepts and Procedures for Bonded Inlays and Onlays. Part I. Historical Perspectives and Clinical Rationale for a Biosubstitutive Approach. Int. J. Esthet. Dent. 2015, 10, 210–227.

30. Stephanie Krifka ,Thomas Anthofer, Marcus Fritzsch, Karl-Anton Hiller, Gottfried Schmalz, Marianne Federlin. Ceramic inlays and partial ceramic crowns: influence of remaining cusp wall thickness on the marginal integrity and enamel crack formation in vito. Oper Dent. 2009 Jan-Feb;34(1):32-42. doi: 10.2341/08-34.

31. Scotti N, Baldi A, Vergano EA, Tempesta RM, Alovisi M, Pasqualini D, Carpegna GC, Comba A. Tridimensional Evaluation of the Interfacial Gap in Deep Cervical Margin Restorations: A Micro-CT Study. Oper Dent. 2020 Sep 1;45(5):E227-E236. doi: 10.2341/19-161.

32. Frankenberger, R.; Hehn, J.; Hajtó, J.; Krämer, N.; Naumann, M.; Koch, A.; Roggendorf, M. Effect of Proximal Box Elevation with Resin Composite on Marginal Quality of Ceramic Inlays in Vitro. Clin. Oral. Investig. 2013, 17, 177–183.

33. Anatavara S, Sitthiseripratip K, Senawongse P. Stress relieving behaviour of flowable composite liners: A finite element analysis. Dent Mater J. 2016;35(3):369-78. doi: 10.4012/dmj.2015-204. PMID: 27251991.

34. JH, Park Jang SH, Hwang IN. Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flowable resin. Oper Dent. 2015 Mar-Apr;40(2):172-80. doi: 10.2341/13-307-L. Epub 2014 Aug 19. PMID: 25136904.

35. Ilgenstein I, Zitzmann NU, Bühler J, Wegehaupt FJ, Attin T, Weiger R, Krastl G. Influence of proximal box elevation on the marginal quality and fracture behavior of root-filled molars restored with CAD/CAM ceramic or composite onlays. Clin Oral Investig. 2015 Jun; 19(5):1021-8. doi: 10.1007/s00784-014-1325-z.

36. Grubbs, T.; Vargas, M.; Kolker, J.; Teixeira, E. Efficacy of Direct Restorative Materials in Proximal Box Elevation on the Margin Quality and Fracture Resistance of Molars Restored with CAD/CAM Onlays. Oper. Dent. 2020, 45, 52–61.

37. Papadogiannis D, Tolidis K, Lakes R, Papadogiannis Y. Viscoelastic properties of low-shrinking composite resins compared to packable composite resins. Dent Mater J. 2011;30(3):350-7. doi: 10.4012/dmj.2010-181.

38. Sandoval MJ, Rocca GT, Krejci I, Mandikos M, Dietschi D. In vitro evaluation of marginal and internal adaptation of class II CAD/CAM ceramic restorations with different resinous bases and interface treatments. Clin Oral Investig. 2015 Dec;19(9):2167-77. doi: 10.1007/s00784-015-1449-9. Epub 2015 Apr 16. PMID: 25877233.