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# INFLUENCE OF PROXIMAL BOX ELEVATION USING TWO DIFFERENT RESIN COMPOSITE VISCOSITIES ON THE MARGINAL ADAPTATION OF CAD/CAM CERAMIC OVERLAYS SUBJECTED TO THERMOMECHANICAL AGING. AN IN VITRO STUDY

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## *ABSTRACT*

**Purpose:** To evaluate the effect of using different resin composite viscosities for elevation of deep cervical margins in maxillary premolars on the margin adaptation of CAD/CAM fabricated lithium disilicate ceramic overlays after exposure to thermomechanical aging.

**Materials and methods:** Thirty maxillary premolars were prepared for MOD indirect ceramic overlays with proximal box extends 2mm below the cementoenamel junction. Teeth were divided into 2 groups according to proximal box elevation (PBE): Control group (group_C) (n=15); with No PBE and intervention group (n=15); which was subdivided into group I_F: mesial surface PBE with flowable composite and group I_B: distal surface PBE with bulk-fill flowable composite. All overlays were milled from lithium disilicate blocks and bonded to prepared cavities with dual cure adhesive resin cement. All samples were subjected to thermomechanical aging, then, marginal gap was evaluated with digital microscope.

**Results:** Two-way ANNOVA revealed that Group_C demonstrated the highest marginal gap values (42.78± 4.949 $\mu$m) before aging and (78.01± 5.767 $\mu$m) after aging, while, Group I_B demonstrated the lowest marginal gap values (39.97± 4.923 $\mu$m) before aging and (71.35± 10.29 $\mu$m) after aging, though the difference between all groups was non statistically significant.

**Conclusions**: Proximal box elevation under indirect ceramic overlays with either bulk-fill and flowable results showed comparable marginal sealing ability to direct bonding of ceramic overlays to cervical dentine. Thermomechanical aging significantly reduced the marginal adaptation, but, all tested restorations exhibited marginal quality within clinically accepted values.

**KEYWORDS:** Proximal box elevation, indirect adhesive overlays, marginal adaptation, premolars, thermomechanical aging.

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## INTRODUCTION

Management of deep interproximal carious lesions has always been a challenge in clinical practice. Interproximal wall loss can complicate the restorative approach, as it's responsible for creating large cavities which are either compound class-II or MOD cavities.[1] These cavity types would be problematic to restore with direct composite without the risking excessive polymerization shrinkage that may negatively impact the restoration's marginal adaptation and subsequently result in microleakage and recurrent caries. In cases with deep interproximal cavities, indirect restorations would be more suitable restorative option as they offer minimal shrinkage induced stresses on the compromised tooth, which can improve restoration marginal adaptation and overall fracture resistance and clinical longevity. [2,3] Subgingivally located interproximal margins are difficult to prepare and finish and even more difficult for impression making, isolation and adhesive cementation of indirect restorations. Despite being the only solution for decades, surgical crown lengthening of deep subgingival margins is sometimes associated with attachment loss, alveolar bone loss and opening of interproximal contacts. Moreover, gingival marginal level after healing is unpredictable. [4,5]

Deep margin elevation (DME), also known as cervical margin relocation (CMR), was first proposed Dietschi and Spreafico [6], and modified by Magne and Spreafico [7]. The procedure aims to providing a reliable coronal margin to deep subgingival cavities after caries removal through the application of successive layers of adhesive resin. Following this procedure, isolation is more reliable and bonding of indirect ceramic restorations is more predictable. [8] Additionally, better access for polymerization is provided by decreasing the cavity depth which allows for better marginal adaptation and decreases polymerization shrinkage. Another advantage to supragingival relocation of indirect restoration margin is providing better access for removal of excess cement allowing for fast gingival healing and less periodontal complications around the newly created restoration margin. [9,10]

Among mutilated posterior teeth, maxillary premolars are the most difficult to restore with predictable clinical longevity. The problem with restoring maxillary premolars with large deep cavities is their high liability to cuspal deflection. Their position in the dental arch combined with the unfavorable force direction and smaller surface area makes premolar restoration more challenging than molars. [11] Advances in CAD/CAM ceramic materials and adhesive bonding strategies lead to paradigm shift in indirect partial coverage adhesive restorations.[12] Adhesive indirect partial coverage restorations that provide cuspal coverage like onlays and overlays were advocated in many literatures for restoration of premolars with extensive loss of tooth structure as a more conservative alternative to full coverage restorations. Posterior indirect adhesive restorations offer the advantage of cuspal protection for weakened premolars while, providing ideal occlusal anatomy, proximal contacts, emergence profile and proper marginal seal. The reduction of polymerization shrinkage coupled with the ability to use high strength ceramic material can offer better protection for premolars against degradation in oral environment and enhance their clinical longevity. [13-16]

Marginal adaptation is pivotal to success and long-term survival of indirect restorations. The presence of marginal discrepancies at tooth/restoration interface enhance plaque accumulation with subsequent risk of leakage, recurrent caries and periodontal affection. [17,18] According to recent literatures, deep margin elevation under indirect partial coverage adhesive restorations provided excellent marginal adaptation and optimum periodontal health. [19-22]

However, there are limited studies investigating the marginal adaptation of posterior indirect adhesive restorations to different viscosities of resin composite for cervical margin relocation. Therefore, the purpose of this study was to evaluate the effect of using different resin composite viscosities for elevation of deep cervical margins in maxillary premolars on the margin adaptation of CAD/CAM fabricated lithium disilicate ceramic overlays after exposure to thermomechanical aging. The null hypotheses were that there would be no difference in marginal adaptation between different composite viscosities or before and after thermomechanical aging.

## MATERIALS & METHODS

The proposal for this study was approved by Institutional Review Board Organization IORG0010868, Faculty of Oral & Dental Medicine, Ahram Canadian University. Research Number: IRB00012891#91.

### Sample Size Calculation:

Based on previous study by Al-Ahmary NM *et al*.[22] sample size of 12 in each group has an 80% power to detect a difference between means of 267.68 with a significance level (alpha) of 0.05 (two-tailed) at 95% confidence intervals. In 80% (the power) of those experiments, the P value will be less than 0.05 (two-tailed) so the results will be deemed "statistically significant". In the remaining 20% of the experiments, the difference between means will be deemed "not statistically significant". Sample size was increased to 15 per group with a total of 30 samples.

### Selection of the study samples:

A total of thirty recently extracted human maxillary first premolars extracted for orthodontic treatment were collected from the department of oral and maxillofacial surgery, Ahram Canadian university. Teeth included were intact, with two completely formed roots, caries free and possess similar buccolingual and mesiodistal dimension as verified by digital caliper (up to 10% discrepancy). All teeth with cracks, caries or coronal restorations were excluded. The inclusion criteria were intact, caries and crack free teeth, while the exclusion criteria were teeth with carious lesions, coronal restorations, cracks, or fractures. The sizes of the selected premolars were measured by digital caliper (Mitutoyo IP 65, Kawasaki, Japan) to verify that they all were nearly similar mesiodistal and buccolingual dimensions at cemento-enamel junction with maximum deviation in dimension of 10%. To remove all external plaque and any depositions, all teeth were subjected to ultrasonic cleaning followed by storing in distilled water with 0.1% thymol at room temperature (Cavitron, Dentsply Sirona, Pennsylvania).

All 30 samples were placed upright in a custom-made cylindrical mold filled with clear acrylic resin (Acrostone, Egypt) 3mm apical to the cementoenamel junction (CEJ).

### Teeth preparation:

30 samples were randomly divided into two groups (n=15/group) according to proximal box elevation PBE performed:

Intervention: (n=15) was further subdivided into two groups (Mesial and Distal surfaces) according to composite viscosity used for PBE:

Group I_F (n=15): mesial surface, PBE with flowable composite.

Group I_B (n=15): distal surface, PBE with bulk fill composite.

**Control: Group C (n=15), No PBE**

To standardize teeth preparation, silicon index (Panasil® Tray Heavy; Kettenbach, USA) was obtained for all teeth before preparation to be used for checking the amount of reduction afterwards. Additionally, optical impression was taken for all teeth with OmniCam intraoral scanner (Dentsply Sirona GmbH, Germany) before preparation using Biocopy mode in CEREC 3D software, for superimposition with postoperative 3D images of the preparations to digitally verify the amount and quality of preparation.

All teeth preparation, PBE and final overlay bonding procedures were done by the same operator, additionally, all overlay fabrication steps were done by the same CAD/CAM specialist.

MOD Adhesive ceramic overlay preparation was based on morphology driven preparation technique (MDPT) by Veneziani M. [1] First, planner occlusal reduction of 1.5 mm on the palatal cusp and 1 mm on the buccal cusp, following the fissure direction was done with diamond flame bur (3117-368-023, Microdont, USA). Internal axial walls were prepared by conical diamond bur with flat-end (3332-487-021, Microdont, USA), with 6-10° divergence angle, and defined rounded internal line angles. Preparation of interproximal box with 1 mm thick butt-joint margin 2 mm below CEJ with flat-end diamond conical bur. Adhesive overlay margin was prepared with hollow chamfer finish line located at the junction between the occlusal inclined plane and the outer axial wall with cylindrical chamfer bur (3038-856-018, Microdont, USA). Preparation was finished with fine grit diamond burs of the same shapes.

Immediate dentin sealing (IDS) technique was done by application of universal adhesive bonding agent (All-Bond Universal. BISCO Inc, USA) to the proximal box and the rest of the cavity with proper agitation using micro brush and left in place for 20 seconds, followed by air thinning to remove excess solvent and to achieve a thin layer of bonding agent. The bonding agent was then light cured for 20s using a LED polymerization device (Elipar™ , 3M ESPE, USA) at 1,200 mW/cm2. [24]

Proximal box elevation was done for intervention group (n=15) using two different viscosities of resin composite on the mesial and distal surfaces of each tooth. Group I_F: flowable composite Spectra ST flow (Dentsply Caulk, Milford, DE, USA) was used for PBE on the mesial surface. First, saddle metal matrix (Tor VM, 1.330- 0.035mm, TOP BM, Russia) was secured around each tooth with a Tofflemire matrix holder (Omni Matrizenspanner, Omnident, Germany), then the flowable composite was applied to the gingival seat in two increments of 1 mm thickness, then, each increment was light cured for 40 seconds. For Group I_B: SDR bulk-fill flowable composite (Dentsply Caulk, Milford, DE, USA) was injected into the prepared gingival seat on the distal surface of the tooth after matrix adaptation, in the form of two increments of 1mm each, each increment was followed by curing for 40 seconds according to manufacturer recommendations. After matrix removal, curing was ensured from all sides. For control group (Group C); no PBE was done. [25]

All prepared samples were checked with digital caliper, then, with silicon index and periodontal probe. Teeth were scanned with intraoral scanner (OmniCam, Dentsply Sirona GmbH, Germany), and the image was superimposed with preoperative scan for reduction verification with PrepCheck feature on CEREC 4.5 software (Dentsply Sirona GmbH, Germany), samples with discrepancy > 0.2mm were excluded.

**Adhesive Ceramic Overlay Fabrication:**

Following digital scanning of prepared teeth with OmniCam intraoral scanner, 30 ceramic overlays were designed using CEREC 4.5 software. No editing was done to the original restoration proposal by the CEREC software in order to maintain the original morphology before preparation for proper standardization. Cement space was set to 50µ.

Overlay restoration milling was done with 4-axis wet milling/grinding machine MCXL (Dentsply Sirona GmbH, Germany), from lithium disilicate CAD/CAM blocks IPS e.max CAD (Ivoclar Vivadent Inc., USA). All restorations were crystallized and glazed in ceramic furnace Programat P310 (Ivoclar Vivadent Inc., USA) according to manufacturer instructions.

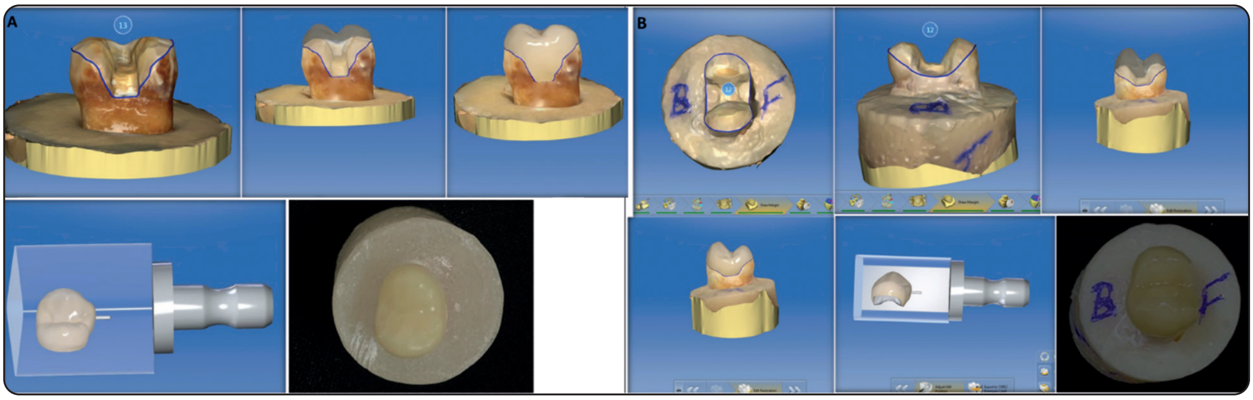

Fig. (1) CAD/CAM fabrication of indirect adhesive ceramic overlays; **A:** Control group, **B:** intervention group (I_F; mesial & I_B; distal)

**Adhesive Cementation of Ceramic Overlays:**

Ceramic overlay surface was conditioned with 9.5% hydrofluoric acid etch (Porcelain etchant, Bisco, USA), for 20 seconds, followed by rinsing and drying for 20 seconds. Silane coupling agent (Porcelain primer, Bisco, USA) was applied to the dried surface, left for one minute then air dried for 20 seconds.

Prepared tooth surface was etched with 37% phosphoric acid etchant (Etch-37, BISCO, USA) for 30 seconds followed by rinsing for 30 second and drying for another 30 seconds. Adhesive resin (All-Bond Universal. BISCO Inc, USA) was applied to the tooth surface then light cured for 20 seconds. Dual cure adhesive resin cement (BisCem®, Bisco, USA) was applied to the intaglio surface of restoration then restoration was seated on the prepared tooth with finger pressure. 5kg vertical load was applied with a special made device, and all excess cement was removed followed by light polymerization for 40 seconds from all surfaces. Samples were stored in distilled water for 24 hours before thermomechanical aging.

**Marginal gap measurement:**

Vertical marginal gap was imaged using U500x Digital Microscope (Guangdong, China) with built-in camera at fixed magnification of 40x. Images were analyzed with digital analysis software (Image J 1.43U, National Institute of Health, USA), and marginal gap was measured at each tooth surface (buccal, palatal, mesial and distal). 3 equidistant landmarks were taken for each surface and measurement was repeated 3 times. Marginal gap data before aging was collected and tabulated for analysis afterwards.

**Thermomechanical aging:**

In order to simulate 6 months in oral environment, samples were subjected to thermal cycling of 5000 cycles at 5 °C–55 °C, with dwell time = 25 s, and lag time = 10 s using (Robota automated thermal cycle; BILGE, Turkey). Followed by 75,000 cyclic loading of 50 N occlusal load at 1.6 Hz frequency in chewing simulator (ROBOTA, Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY). [25]

Vertical Marginal gap was re-assessed after thermomechanical aging utilizing the same reference points on each sample and with the same magnification. All data were collected, tabulated and statistically analyzed.

**Statistical analysis:**

One-way analysis of variance was performed followed by Tukey's post-hoc test if showed significance between groups. Two-way ANOVA compared the effect of each factor (material and aging). Sample size **(n=15/group)** was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence level.

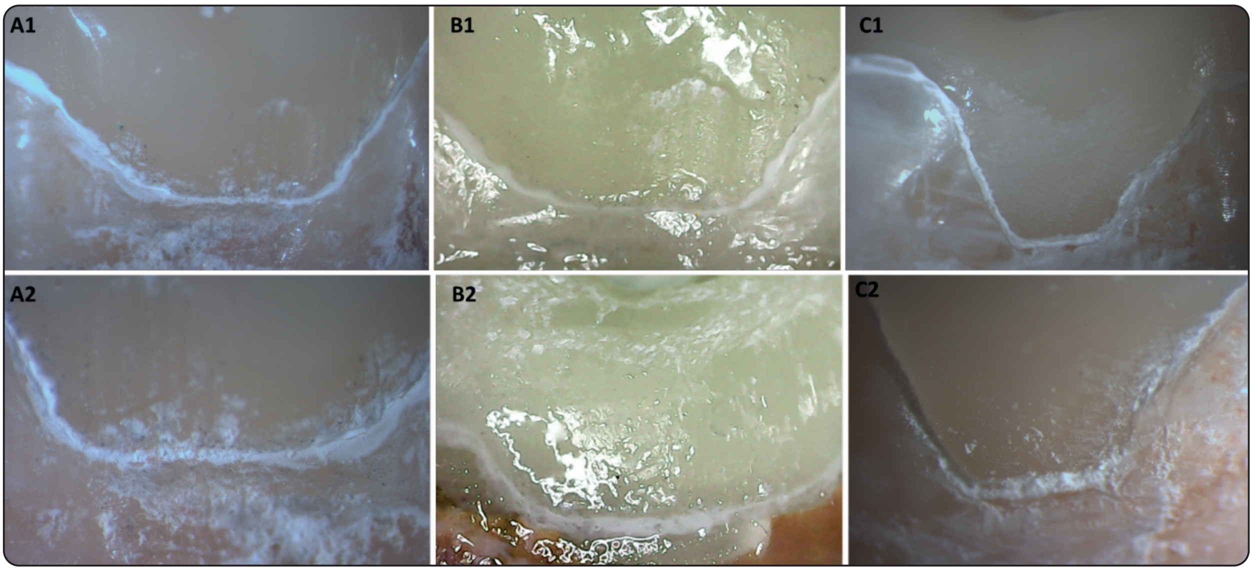


**Fig. (2):** Marginal gap assessment by digital microscope, magnification 40x. **A**: Group I_F, **B**: Group I_B, and **C**: Group C, **1:** before thermomechanical aging and **2:** after thermomechanical aging

The results were analyzed using Graph Pad Instat (Graph Pad, Inc.) software for windows. A value of $P \leq 0.05$ was considered statistically significant.

## RESULTS

Descriptive statistics of vertical marginal gap ($\mu$m) showing mean, standard deviation (SD) and 95% confidence intervals (low and high) values for all groups before and after thermal aging are summarized in **Table (1)** and graphically drawn in **Figure (3)**.

**Total effect of DME material type on vertical marginal gap mean values:**

Regardless of thermomechanical aging, it was found that the difference between groups mean values was ***statistically non-significant*** *(p=0.1269>0.05)* as demonstrated by two-way ANOVA test where **Group C** demonstrated the highest marginal gap values **(42.78± 4.949 $\mu$m)** before aging and **(78.01± 5.767 $\mu$m)** after aging, while, **Group I_B** demonstrated the lowest marginal gap values **(39.97± 4.923 $\mu$m)** before aging and **(71.35± 10.29 $\mu$m)** after aging. (***Gr_C ≥ Gr_I_F ≥ Gr_I_B).*** **Table (1)** and **Figure (3)**

**Vertical marginal gap ($\mu$m) for each DME material group:**

***For Gr_I_F***: it was found that after thermomechanical aging, gap mean values **(76.67± 9.431 $\mu$m)** was higher than gap before **(41.56± 3.156 $\mu$m).** This was ***statistically significant*** (p=< 0.0001< 0.05) as revealed by paired t-test. **Table (2)** & **Figure (3)**

***For Gr_I_B***: it was found that after thermomechanical aging, gap mean values **(71.35± 10.29$\mu$m)** was higher than gap before **(39.97± 4.923$\mu$m).** This was ***statistically significant*** (p=< 0.0001< 0.05) as revealed by paired t-test. **Table (2)** & **Figure (3)**

***For Gr_C***: it was found that after thermomechanical aging, gap mean values **(78.01± 5.767$\mu$m)** was higher than gap before **(42.87± 4.949$\mu$m)**. This was ***statistically significant*** (p=< 0.0001< 0.05) as revealed by paired t-test. **Table (1)** & **Figure (3)**

**Comparison between all groups either before or after thermomechanical aging:**

There was statistically ***non-significant*** (p > 0.05) between main groups as verified by ANOVA test. **Table (1)** & **Figure (3)**

TABLE (1) Comparison of marginal gap results (Mean values ±SDs) between all groups before and after thermal aging

| *Variable* | | *Thermomechanical aging* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Before* | | | | *After* | | | | *Statistics* |
| | | *Mean* | *± SD* | *95% CI* | | *Mean* | *± SD* | *95% CI* | | *t-test* |
| | | | | *Low* | *High* | | | *Low* | *High* | *P value* |
| *Main group* | *Gr_I_F* | 41.56$^A$ | 3.156 | 39.81 | 43.31 | 76.67$^A$ | 9.431 | 71.45 | 81.89 | < 0.0001* |
| | *Gr_I_B* | 39.97$^A$ | 4.923 | 37.25 | 42.7 | 71.35$^A$ | 10.29 | 65.66 | 77.05 | < 0.0001* |
| | *Gr_C* | 42.87$^A$ | 4.949 | 40.13 | 45.61 | 78.01$^A$ | 5.767 | 74.82 | 81.2 | < 0.0001* |
| *Statistics* | *P value* | 0.2117 ns | | | | 0.1043 ns | | | | |

***Different letters in same column indicating significant between groups (p<0.05)***

****; significant (p<0.05)*** ***ns; non-significant (p>0.05)***

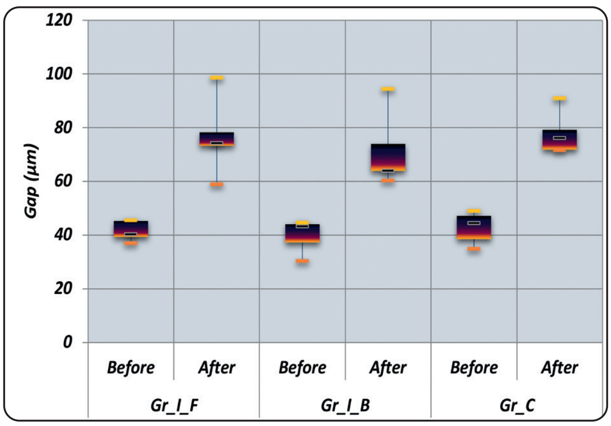

Fig. (3) Box plot chart comparing vertical marginal gap values between all groups before and after thermomechanical aging

### Effect of thermomechanical aging on vertical marginal gap

Irrespective of DME material, it was found that thermomechanical aging ***significantly affected*** *(p=<0.0001 < 0.05) vertical* marginal gap mean values, as proved by two-way ANOVA, where the marginal gap after thermomechanical aging recorded higher mean value than before in all groups. **Table (1)** and **Figure (3)**

## DISCUSSION

Treatment of large carious cavities with deep interproximal extension below CEJ in premolars is a complex procedure especially when a conservative indirect adhesive restoration is chosen instead of full coverage crown. [26] Deep margin elevation was recommended in many literatures as a reliable method for managing deep interproximal margins with favorable periodontal response. [27-30] It allows for proper control over indirect restoration preparation as well as the following steps as digital impression, restoration try in and final adhesive cementation. Nevertheless, strict clinical protocol should always be followed in proximal box elevation (PBE), through isolation, matrix application with close adaptation to the cavity margin and carefully executed bonding procedure. [28]

In our present study, metal matrix was used to secure composite material to the margin. Metal matrix is known to be superior to transparent matrix in adaptation to cavity walls. [31] Additionally, carful light polymerization was done from all sides to ensure complete polymerization of the applied composite materials. [1]

Immediate dentin sealing (IDS) was performed in this study to ensure strong adhesion to freshly cut dentin. (23) Since IDS technique improves the bond strength of dentin to the restorations regardless of the adhesive strategy used. (32) Studies proved that the use of IDS technique produced significantly higher mean bond strength as compared to delayed dentin sealing (DDS). (33.34) Performing the IDS together with the PBE technique increases retention, decreases marginal leakage, and has better bond strengths. (35) Additionally, it lowers postoperative sensitivity. (36)

Adhesive ceramic overlay preparation in this study was done following morphology driven preparation technique (MDPT) with hollow chamfer margin design. This preparation technique ensures minimal cutting of the tooth structure by following the tooth original morphology. In addition, margin design ensures maximum tooth conservation by providing preparation margin with smaller width than shoulder margin that is left only for interproximal gingival seat where risk of fracture is high. (1)

Furthermore, hollow chamfer margin design provides larger area of enamel for more profound adhesion, as well as, a gradual transition at the tooth-restoration interface which allows for better esthetic transition and color blending. (37)

The overall results of this study revealed margin gap results for adhesive ceramic overlays within the clinically accepted values. Our results showed that there was no statistically significant difference between the marginal adaptation of CAD/CAM fabricated overlay bonded directly to dentin without proximal box elevation and those bonded to proximally elevated cavities. Thus, the first null hypothesis was accepted.

This was in agreement with Müller *et al.* (38), who found that the marginal integrities of bonding inlays directly to dentine are not different from bonding inlays to a proximal box, which has been elevated by a composite filling material. This was also in agreement with Sandoval *et al.* (39), who found that flowable or restorative composites when being used as liner under CAD/CAM fabricated ceramic inlays, produce marginal and internal adaptation similar to restorations placed directly on dentin. Köken *et al.* (40), also reported similar results when they compared directly placed CAD/CAM composite overlays on dentine with overlays bonded to DME cavities with either micro-hybrid or flowable composites.

The results of the present study were against Frankenberger et al. (41), who found that bonding glass–ceramic directly to dentin showed the highest amounts of gap-free margins in dentin compared to bonding to PBE with self-adhesive resin cements, that exhibited significantly more gaps in dentin. Additionally, Ilgenstein *et al.* (42), also found that the marginal quality was better in terms of both marginal quality and fracture resistance in cases cemented directly to dentin without proximal box elevation. These differences in results could be attributed to the difference in DME technique, matrix system and resin composite materials used from our study.

Artificial aging is known to have a detrimental effect on both composite and ceramic restorations. (25) Thus, for proper simulation of the oral conditions, cyclic loading in addition to thermal cycling were done to all samples in this study. The second null hypothesis for this study was rejected as, our results showed that thermomechanical aging significantly affected the marginal adaptation in all study groups as the marginal gap was significantly higher after thermomechanical aging in all samples. These findings were in agreement with Roggendorf *et al.* (43), as they found severe margin deterioration in PBE composite inlays. On the other hand, our results regarding thermomechanical aging effect disagrees with Müller *et al.* (38), and Spreafico et al. (44), who found that thermomechanical cycling has no effect on the quality of cervical margins. Frankenberger et al. (41), and Ilgenstein *et al.* (42), reported that artificial aging had an effect on margin quality of both DME and non-elevated partial ceramic restorations but the effect was not significant.

Regarding the material used for proximal box elevation, there was no significant difference between the two viscosities used. It was found by Dietschi et al., (45) the use of material with intermediate modulus of elasticity such as flowable composites produced better internal adaptation when compared with more rigid materials. A flowable composite has the ability to absorb stresses when used for proximal box elevation (46). This layer not only absorbs the polymerization shrinkage stresses but also has the ability to absorb functional stresses. How effective this layer will be depending on many factors such as its thickness and modulus of elasticity (47). On the contrary, Rocca et al., found that there was no difference in the marginal adaptation with different types of composites (48). Zhang H *et al*. (35), tested the bulk-fill SDR and traditional resin composite to find a solution for the microleakage problem. They found that there was no significant difference between both types of composite.

Results of this study are uplifting regarding the use of PBE under indirect adhesive restorations. In cases where optimum isolation is achievable, PBE can be performed to make the rest of producers of overlay preparation, impression and cementation easier with more predictable outcome. While, in other cases where isolation is difficult, surgical correction is necessary, followed by restoration construction and direct bonding to the tooth (21).

Nevertheless, the in vitro model is one of this study limitations. Despite the carful standardization and employment of thermomechanical aging in this study for close simulation of clinical situations, intraoral environment is extremely complex with more chemical, mechanical and biological factors that can affect the restoration survival and long-term performance. Further clinical studies are needed to evaluate such restorations in actual clinical service conditions. Moreover, additional clinical and laboratory investigations are needed to compare machinable composite materials to ceramic materials behavior to PBE.

## CONCLUSIONS

Within the limitations of this study, proximal box elevation under indirect ceramic overlays with either bulk-fill and flowable results showed comparable marginal sealing ability to direct bonding of ceramic overlays to cervical dentine. Thermomechanical aging significantly reduced the marginal adaptation, but, all tested restorations exhibited marginal quality within clinically accepted values.

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