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EVALUATION OF CERVICAL MARGIN RELOCATION FOR CAD/CAM ZIRCONIA CROWNS USING DIFFERENT COMPOSITE RESIN MATERIALS AND CAVITY DESIGNS: MARGINAL GAP AND MICROLEAKAGE

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ABSTRACT

This study evaluated the effect of the material and the extension of the relocated margin on the marginal adaptation of the extra coronal restoration and microleakage at the tooth/resin interface after thermo-mechanical cyclic loading. Materials and methods: 196 teeth were divided into six groups according to type of cavity design and build-up restoration. All the groups received a standardized MO cavity preparation. The gingival seat was located 2 mm above the CEJ. Group I was without any modification and restored with direct composite. For Group II, III and IV the gingival seat extended 2mm below the CEJ and restored with direct, flowable, indirect composite respectively. Group V had MOD cavity where the proximal boxes had the same criteria of the mesial preparation of Groups II-IV. Samples of Group VI received the same preparation as Groups II, III and IV but was extended another 4mm in the buccal direction. Groups V and VI were restored with direct composite. Marginal gap and microleakage scores were evaluated after chewing simulation. Results: Group VI and IV showed the highest mean margin value compared to different cavity designs and materials used for CMR respectively, however within clinically acceptable range. Group III showed the highest microleakage scores. Conclusions: The use of CMR with single or multiple narrow cavities is more favorable than with wide cavities. CMR is a logical option in teeth with deep proximal cavities that needs to be crowned.

INTRODUCTION

Since the last decade of the 20th century, considerable advancement in adhesive materials and techniques has been achieved, leading to changing the restorative approach in the posterior area. Composite resin has replaced amalgam restoration in most of the cases. Composite resin restorations are placed in the posterior area not only because

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they are esthetically appealing, but also for the bio-economics concept where maximum amount of healthy tooth structure is conserved [1].

Microhybrid or nano-particle composites are deemed most suitable for all types of cavities due to their excellent mechanical and physical properties; they have similar elastic modulus to dentin, radiopaque besides a comparable wear resistance to that of enamel and amalgam [2].

However, the problem of polymerization shrinkage has not yet completely resolved, therefore, adhesively cemented restorations using indirect or semi-direct techniques are recommended in cases of large dimension cavities and where cuspal coverage is indicated to reduce the polymerization shrinkage of resin materials which occurs outside the cavity [3].

The restoration of large proximal cavities that extends beyond the gingival margin and/or the cemento-enamel junction has been a very common clinical scenario which leaves the operator facing multiple challenges in addition to the before mentioned polymerization shrinkage: the possibility of violating the biologic width, the difficulty in isolation of the operating field [4], absence of enamel for proper bonding [5] as well as difficulty of impression taking and adhesive luting of restorations [6, 7] and successful finishing and polishing of the margins [4].

A possible clinical solution for this problem is orthodontic extrusion yet it is rather a time-consuming procedure.[8] Crown lengthening is another solution that involves surgical displacement of the supporting tissues in the apical direction, nevertheless this can cause attachment loss and may alter the proximity of root concavities and furcations[6] besides the decreased desire of the patient for such invasive procedure [8].

A practical, less invasive approach was introduced in ***1998*** by ***Dietschi and Spreafico*** [9]. They suggested the application of resin composite material to raise the subgingival cervical margin in the coronal direction to reposition the margin supragingivally with a subsequent indirect restoration. The rationale behind this idea was the ease of impression taking, isolation and adhesive luting of the indirect restoration over the relocated, now supragingival, composite resin margin.

They referred to this technique as Cervical Margin Relocation (CMR). But the same idea can be found in the literature as Deep Margin Elevation (DME)[10]. Coronal margin relocation and proximal box elevation are sometimes heard between clinicians.This idea emerged as these types of cavities were originally suggested to be filled with the "open-sandwich technique" to overcome the challenges associated with placement of a restoration in such deep cavities where the base is subjected to the oral environment underneath [11].

At the start, glass ionomer cements were suggested to be the base material [11] in addition to resin modified glass ionomer[12] polyacid modified resin composites[13] and flowable composites[14]. Several in vitro and in vivo studies have emerged since then addressing the mechanical and biological properties of different techniques and materials used. Most of the papers combined the CMR concept with indirect intracoronal restorations [15-20].

The problem is more complicated when a tooth with deep proximal cavity is endodontically treated, especially in upper premolars. These teeth, with two steep cusps, are liable to wedging occlusal forces mandating cuspal coverage to protect the teeth from fracture. Full coverage crowns have been commonly used for this purpose for a long period of time [21].

Since few decades, an extensive debate has existed whether a full ferrule, partial ferrule or no ferrule at all should be present when an endodontically treated teeth (ETT) is being restored. The superiority of the full ferrule has been demonstrated in several researches [22-24], this concept applies to ETT whether it is restored with a post and core or only with a composite core [25-27], albeit, a partial ferrule is still considered better than no ferrule at all and should not be ruled out [28]. Some investigators [29] suggested that, with regards to the tooth position, it is of more value to consider the location of the available sound tooth structure to resist the masticatory stresses than to have a 360° ferrule of circumferential dentine.

Other researchers advocated that the direction of the force is a more deciding factor when choosing the treatment plan for ETT. The lateral stresses induced on anterior teeth aren't necessarily anticipated in the posterior teeth where more vertical forces are likely to occur. Hence, applying the concept of all-around ferrule, which is advocated primarily for anterior teeth, may not be needed for posterior teeth with more vertical component of occlusal stresses[22,30]. In the same context, two reviews concluded that favorable occlusal design of the prosthesis is probably more important than the type of restoration used to restore structurally compromised ETT[31, 32].

Jotkowitz and Samet (2010) [33] recommended that if it is only the proximal wall/s missing and there is no extensive lateral forces anticipated, a non-complete ferrule seems to be a better idea than crown lengthening and 360° ferrule. As premolars, in particular the maxillary ones, are regarded to be in the esthetic zone and crown lengthening procedures can significantly compromise the esthetics, moreover, these teeth frequently have a non-favorable root configuration. Therefore, a meticulous plan should be performed to weigh the biomechanical benefits of the all-around 360 ° ferrule against the damaging effects of crown lengthening including those to the neighboring teeth and with regards to bone preservation for the provision of implant therapy should it be required at any time.

There is no enough evidence for the use of CMR in combination with extra coronal crowns. Hence, the aim of this study was to evaluate the effect of the material and the extension of the relocated margin on the marginal adaptation of the extra coronal restoration and microleakage at the tooth/resin interface after thermo-mechanical cyclic loading. Three null hypotheses were tested:

1. There is no difference in the vertical marginal gap distance of the crown regardless the extent of the CMR if the relocated margins were placed mesially only, mesially and distaly or continuous from the mesial till the buccal wall.
2. There is no difference in the vertical marginal gap distance of the crown regardless the material used for CMR.
3. There is no difference in the microleakage at the tooth/resin interface regardless the material used for CMR.

MATERIALS AND METHODS

Sample calculation and selection:

Using the statistical power analysis G*power version 3.1, the sample size required for power 0.95 and a = 0.05 is N=138; 23 for each group. A total of 138 intact human upper premolars with approximately the same size, extracted for periodontal or orthodontic causes, were used after patients' consent. The teeth were cleaned and the periodontal tissues were removed. The teeth were then soaked in thymol 0.1% for not more than 2 months.

Epoxy resin (Chemapox 150, CMB, Cairo, Egypt) was mixed according to manufacturer's instructions and poured into ice cube then the teeth were placed vertically using a special jig into the epoxy resin 3mm below the CEJ.

Sample preparation and grouping:

All teeth were root canal treated in a standardized procedure as follows; the working lengths were determined by periapical x-ray. K-file no. 10 or 15 was used as initial file, then apical area was prepared by sequences of k-files with same working length up to k-file 25, ProTaper Next® X1, X2, X3, X4, X5 files were used depending on the size of the canal. Canal irrigant (2.5% sodium hypochlorite) and lubricant (GlydeTM File Prep (Dentsply Maillefer, Ballaigues, Switzerland) were used between each file. Then, root canals were obturated by lateral condensation technique with gutta percha. Access cavities were sealed with a nano-hybrid composite filling (Tetric N-Ceram, Ivoclar Vivadent, Schaan, Lichtnestein).

As shown in (Table 1) (Figure 1), the teeth were randomly divided into six equal groups according to type of cavity design and build-up restoration. All the groups received a standardized occluso-mesial (MO) cavity preparation using high-speed diamond burs. The proximal box shape preparations were 2mm in the mesio-distal direction and 4 mm in the bucco-lingual direction. The gingival seat was located 2 mm above the cemento-enamel junction (CEJ).

Group I featured the standardized preparation without any modification. For Group II, III and IV the gingival seat was extended 2mm below the CEJ. Group V cavity was designed with mesio-occluso-distal (MOD) cavity where the 2 proximal boxes had the same criteria of the mesial preparation of Groups II-IV with the gingival seat of the preparation 2 mm below the CEJ both mesially and distally. Samples of Group VI received the same preparation as Groups II, III and IV nevertheless the cavities were extended from the proximal box another 4mm in the buccal direction.

TABLE (1): Description of the experimental groups

	Cavity Design	Build-up Restoration	Extra-coronal restoration
Group I	MO cavity 2 mm above CEJ	Direct composite filling	Full contour zirconia crown
Group II	MO cavity extended mesially 2mm below CEJ	Direct composite filling	Full contour zirconia crown
Group III	MO cavity extended mesially 2mm below CEJ	3-mm flowable composite on gingival seat then direct composite filling	Full contour zirconia crown
Group IV	MO cavity extended mesially 2mm below CEJ	Indirect composite filling cemented with self-adhesive resin cement	Full contour zirconia crown
Group V	MOD cavity extended mesially and distally 2mm below CEJ	Direct composite filling	Full contour zirconia crown
Group VI	OMB Cavity extended mesially and buccaly 2mm below CEJ	Direct composite filling	Full contour zirconia crown

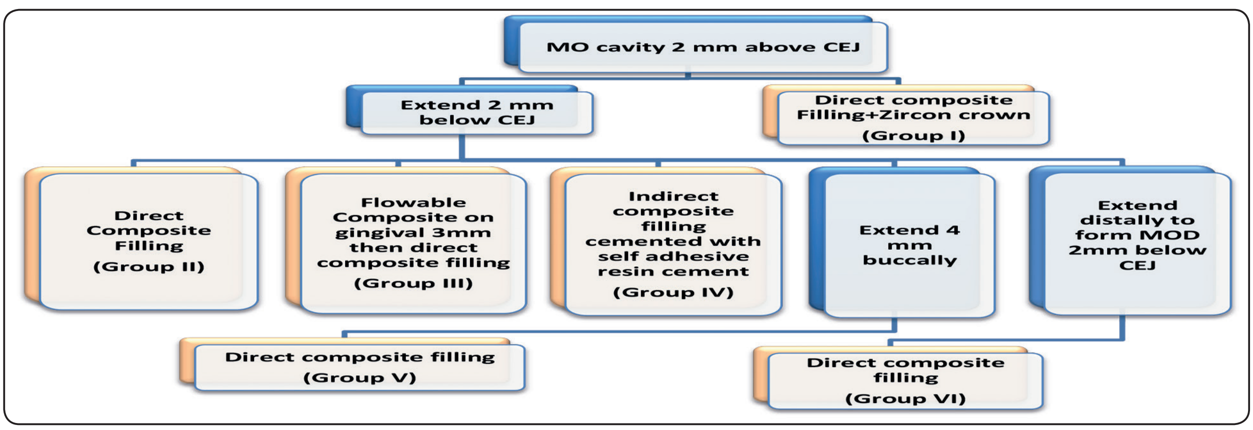

Fig. (1) : Flow chart showing the different groups with different materials and cavity extensions

Samples of groups I, II, III, V, VI were etched with 37% phosphoric acid (N-Etch, Ivoclar Vivadent, Schaan, Lichtenstein) for 30 seconds on the enamel and 15 second on the dentin then rinsed with water for 15 second. A universal bonding agent (Tetric N-Bond Universal, Ivoclar Vivadent, Schaan, Lichtenstein) was applied and cured with a photo-polymerizing unit (Blue phase N, Ivoclar Vivadent, Schaan, Lichtenstein) for 10 seconds. Metal matrix bands were applied and the cavities for Groups I, II, V, VI were filled with a nano-hybrid composite filling (Tetric N-Ceram, Ivoclar Vivadent, Schaan, Lichtnestein) which was applied incrementally and polymerized according to manufacturer's instructions. Whereas for Group III, the gingival seat was filled with two increments of 1.5 mm thickness of flowable composite (Tetric N Ceram Flow, Ivoclar Vivadent, Schaan, Lichtenstein). Each increment was light-cured for 40 seconds according to manufacturer's instuctions, then the rest of the cavity was filled with a nano-hybrid composite filling (Tetric N-Ceram, Ivoclar Vivadent, Schaan, Lichtnestein) as described before.

Addition Silicone impressions (Elite HD, Zhermack, Italy) were taken for Group IV samples and poured with improved stone. A separating medium was applied to stone dies after setting then indirect composite inlays were fabricated using nano-hybrid composite filling (Tetric N-Cerm. Ivoclar Vivadent, Schaan, Lichtenstein) which was applied incrementally and polymerized according to manufacturer's instructions and tried for fit, cemented with dual-cure self-adhesive resin cement (Multilink Speed, Ivoclar Vivadent, Schaan, Lichtenstein). After 3 second of curing time, the excess was removed then full curing for 40 seconds was performed. All the restorations were finished with Pop-on discs (3m Espe, Seefeld, Germany) according to manufacturer's instructions.

All the samples were prepared to receive all-ceramic crowns with a 1 mm rounded shoulder finish line, which was located 1 mm above the CEJ and 1.5 mm occlusal preparation (Fig 2). A universal bonding agent (Tetric N-Bond Universal, Ivoclar Vivadent, Schaan, Lichtenstein) was applied to the prepared teeth and cured with a photo-polymerizing unit for 20 seconds.

The prepared teeth were restored using a CAD/CAM system (Amann Girbach, Koblach, Austria) with full-contour all ceramic zirconia crowns (Ceramill Zolid, Amann Girrbach, Koblach, Austria). The crowns were fabricated with a maximum of 2 mm occlusal height at the cusp tip with a standardized occlusal table from the CAD/CAM software library. The crowns were sintered according to manufacturer's instructions, sandblasted with 50 μm alumina particles, cleaned and conditioned using a universal restoration primer (Monobond N, Ivoclar Vivadent, Schaan, Lichtenstein) and cemented using self-adhesive resin cement ((Multilink Speed, Ivoclar Vivadent, Schaan, Lichtenstein) under finger pressure for 10 minutes. (Fig.3) & (Table 2).

Margin measurements

All the samples were photographed before and after chewing simulation by the same operator from each surface at 3 pre-marked equidistant points with a digital microscope (Scope Capture Digital Microscope, Guangdong, China) at 45X fixed magnification. Measurement of the marginal gaps was performed using a digital image analysis system (Image J 1.43U, National Institute of Health, USA) after calibration with a ruler.

Chewing simulation

Thermo-cycling was performed in a four-station chewing simulator (Robota, Ad-Tech Co, LTD, Germany) where each sample was tightened with a screw to one of the chambers (Fig.4, 5). A weight of 5 kg, comparable to 49 N of chewing force was exerted. The test was repeated 75000 times to clinically simulate the 6 months chewing condition, according to previous study [34].

TABLE (2) list and description of the materials used.

Description	Commercial name	Manufacturer	Composition
Etchant	N Etch	Ivoclar Vivadent, Schaan, Lichtenstein	37% phosphoric acid gel
Universal adhesive	Tetric N Bond Universal	Ivoclar Vivadent, Schaan, Lichtenstein	HEMA, 10-MDP, bis-GMA, MCAP, D3MA, ethanol, water, highly dispersed silicon dioxide.
Nano-hybrid composite	Tetric N Ceram	Ivoclar Vivadent, Schaan, Lichtenstein	Dimethacrylates, additives, catalysts, stabilizer sand pigments, barium glass, ytterbium trifluoride, mixed oxide and prepolymerized filler (prepolymers) (56% vol.)
Flowable composite	Tetric N Ceram Flow	Ivoclar Vivadent, Schaan, Lichtenstein	Monomethacrylates, dimethacrylates, barium glass, ytterbium, trifluoride, copolymers and ivocerin
Adhesive resin cement	Multilink Speed	Ivoclar Vivadent, Schaan, Lichtenstein	Dimethacrylates and acidic monomers, barium glass, ytterbium trifluoride fillers by 40 vol%, co-polymer and highly dispersed silicon dioxide.
Full contour zirconia	Ceramill Zolid	Amann Girrbach, Koblach, Austria	$ZrO_2 + HfO_2 + Y_2O_3$: ≥ 99.0, Y_2O_3: 8.5 – 9.5, HfO_2: ≤ 5, Al_2O_3: ≤ 0.5 and Other oxides: ≤ 1

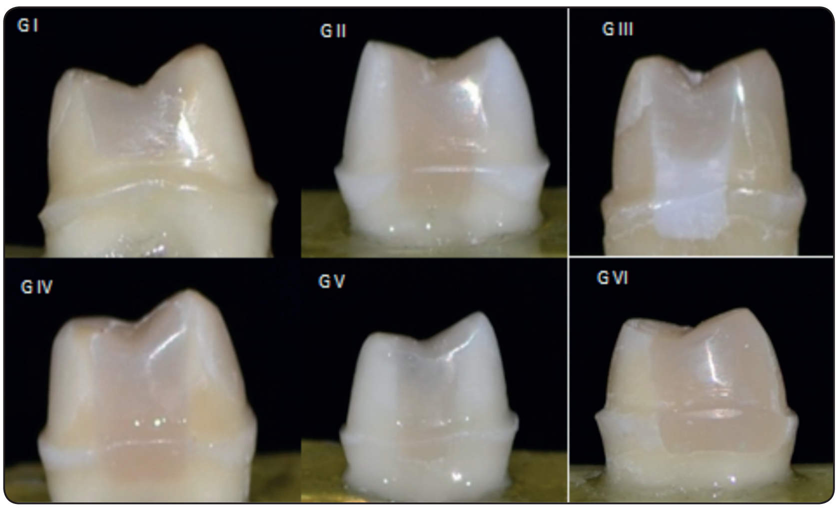

Fig. (2): Representative photographs of different groups after restoration placement and preparation to receive all ceramic crowns.

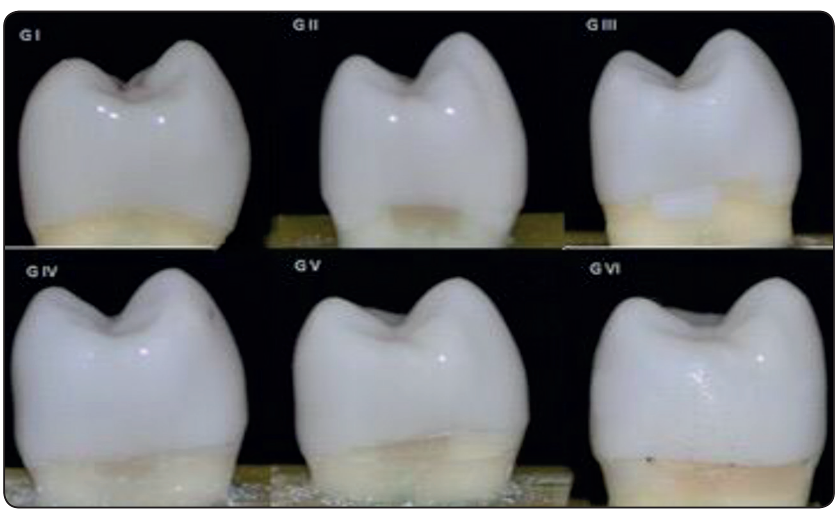

Fig. (3): Representative photographs of different groups after cementation of all ceramic crowns

Microleakage measurements

After loading, samples of groups I, II, III and IV were taken for microleakage testing. 2 coats of nail polish were applied to the crowns and roots of the samples except 1 mm around th margins of the restorations of groups II, III, IV. Group I composite margin was under the zirconia crown and was taken as control. After the nail polish had dried, the specimens were immersed in 2% Methylene Blue dye for 24 hours. After removal from the dye, the teeth were rinsed thoroughly and stored in distilled water. Then, each tooth was sectioned mesiodistally across the center of the restoration using a diamond disk (Horico, Germany). The sectioned teeth were examined under a stereomicroscope at 15x magnification and the amount of dye penetration was measured. Scoring criteria were calculated as follows, score 0 for no dye penetration, score 1 for dye penetration till 0.5mm of the gingival seat, score 2 dye penetration till 1 mm of the gingival seat, Score 3 for dye penetration till 1.5 mm of the gingival seat and, score 4 represented dye penetration till 2 mm of gingival seat and involving the axial wall.

Statistical analysis

Data explored for normality using Shapiro Wilk test and the vertical marginal gap distance results showed parametric distribution. One Way ANOVA used to compare between tested groups followed by Tukey's HSD post hoc test for multiple comparisons. For microleakage; Kruskal Wallis test used to compare between groups followed by multiple comparison with Dunn Bonferroni correction. Significant level was set at p=0.05. Statistical analysis was performed using IBM SPSS (version 23, Armonk, NY, USA)

RESULTS

1. Effect of cavity design on marginal gap distance of the crown

Marginal gap distance mean values (Table 3, Figure 6) demonstrate that Group VI showed the highest mean marginal gap value, which was statistically significant compared to Groups I & II although not significant with Group V. Whereas Group V showed higher mean margin values than Groups I and II however the difference was not statistically significant. Groups I and II showed the least margin mean values with no significant difference between them.

2. Effect of CMR material and technique on marginal gap distance of the crown

Marginal gap distance means (Table 4, Figure 7) demonstrate that Group IV showed the highest mean value which was statistically significant compared to Groups I and II although not significant with Group III. Whereas Group III showed higher margin values than Groups I and II despite being insignificant compared to Group II. Groups I and II showed the least margin mean values with no significant difference between them. (Figure 8)

Fig. (4,5) : Chewing simulation

TABLE (3): Marginal gap distance mean values among tested groups (effect of cavity design).

	Group I	Group II	Group V	Group VI	p-value
Margin gap distance in μm	53.9±9.7[a]	55.5±6.8[a]	59.3±8.7[ab]	67.6±8.7[b]	0.001

Different letter within row indicates significant difference (Tukey's HSD)

TABLE (4): Marginal gap distance among tested groups (effect of CMR material and technique).

	Group I	Group II	Group III	Group IV	p-value
Margin gap distance in μm	53.9±9.7[c]	55.5±6.8[bc]	64.4±10.9[ab]	68.2±7.1[a]	<0.001

Different letter within row indicates significant difference (Tukey's HSD)

TABLE (5): Microleakage scores frequency distribution (percentages) on tooth margins among the different groups tested.

	Group I		Group II		Group III		Group IV		p-value
	n	%	n	%	N	%	n	%	
score 0	23	100.0%	7	30.4%	0	0.0%	1	4.3%	<0.001
score 1	0	0.0%	13	56.5%	2	8.7%	7	30.4%	
score 2	0	0.0%	1	4.3%	9	39.1%	5	21.7%	
score 3	0	0.0%	2	8.7%	10	43.5%	9	39.1%	
score 4	0	0.0%	0	0.0%	2	8.7%	1	4.3%	
Rank	a		b		c		c		

Different letter within row indicates significant difference (Dunn Bonferroni)

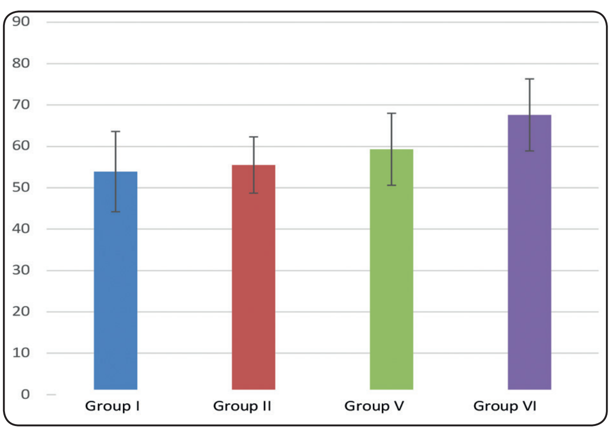

Fig. (6): Distribution of Marginal gap distance among tested groups (effect of cavity design)

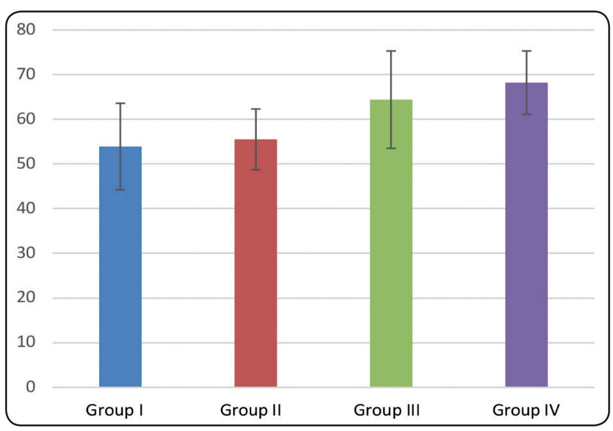

Fig. (7): Distribution of Marginal gap distance among tested groups (effect of CMR material and technique)

3. Effect of CMR material and technique on microleakage at tooth\restoration interface

Microleakage scores (Table 5, Figure 9) demonstrated that Groups III has the highest leakage score with higher prevalence of scores III and IV with significant difference between Group III and all the other groups except Group IV. Group I has the least leakage score with the exclusive prevalence of score 0 and there is significant difference compared to all the other groups. (Figure 10)

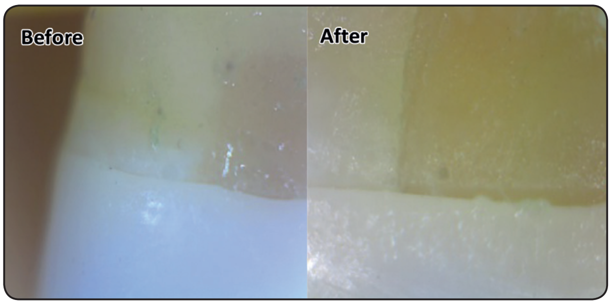

Fig. (8): Representative photos of the margins before and after thermo-mechanical aging

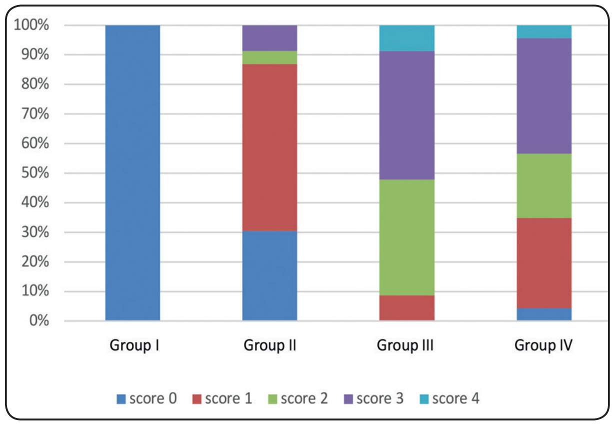

Fig. (9): Distribution of scores among different groups

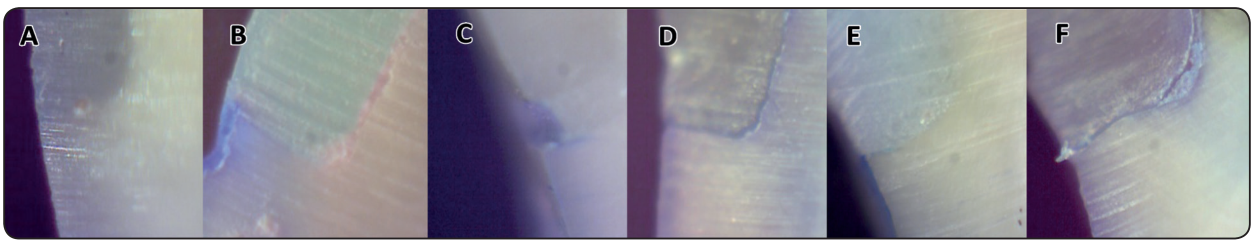

Fig. (10): Representative photos of microleakage scores where: A&B represent scores 0&1 with direct composite, C&D represent scores 2&4 with flowable composite and E&F represent scores 3&4 with indirect composite respectively

DISCUSSION

Large carious lesions in the molar-premolar area with defects extending to cemento-enamel junction inter proximally represents a great challenge for dentists especially when the tooth is advised for full coverage where reinforcement of the remaining tooth structure is indicated. In such cases, the major problem facing dentists is the biological problem that denotes the possible violation of the biologic width; in which a recommended distance of about three mm between the restorative margins and the alveolar crest is advocated to avoid harmful effects on adjacent soft and hard periodontal tissues [35].

Moreover, technical problems also present in such cases including, difficulties in tooth preparation subgingivally, impression taking, and the adhesive cementation of the final extra-coronal restoration [4]. "Cervical margin relocation" (CMR) technique was introduced in order to make the clinical procedures easier to accomplish [9]. It includes, the introduction of composite resin in the deepest portion of the proximal gingival seat which aims to reposition the cervical margin above the gingival margin to become easily accessed [10].

The aim of the present study was to evaluate the effect of the material and the extension of the relocated margin on the marginal adaptation of the extracoronal restoration after thermo-mechanical cyclic loading.

In this in-vitro study, artificial aging was performed using a chewing simulator in combination with thermo-cyclic protocol which is a well-established approach to simulate the clinical situation[36-38]. The benefit of this method is that, for all specimens, stress is standardized and reproducible.

Full coverage extra-coronal restorations were selected as a standard restoration for root canal treated upper premolars [39-47]. On top of that, each group has a different amount of missing tooth structure which may affect the stress distribution for each group, thus full coverage restoration was suggested to standardize the stress pattern among the different groups.

There was excellent margin adaptation of the crowns for all the groups with no significant difference between them. However, after thermo-mechanical loading, the margins deteriorated significantly as reported by several authors [17,48].

The first null hypothesis tested which suggested that there is no difference in the vertical margin gap distance of the crown if the relocated margins were placed mesially only, mesially and distally or continuous from the mesial till the buccal wall was partially rejected as there was a statistically significant difference in the vertical margin gap distance between Group extended and Group I (control group) besides Group II but the difference was not significant with Group V. Group I didn't show any significant difference in the vertical margin gap distance compared to Group II or Group V. These results suggest that the presence of a small "island" of filling along the tooth circumference, as represented by Groups II (mesial) or Group V (mesial and distal) does not contribute significantly to the support of the crown which makes it comparable to Group I where the whole crown margin is resting on the enamel. These results are in accordance with the results obtained by ***Spreafico et al (2016)*** [47] who found no difference in marginal quality between crowns with mesial CMR and those without CMR.

This is not the case if this "island" is extended to involve a significant amount of the tooth circumference as represented by Group VI. In this case, the contribution of the composite filling in resisting the occlusal load is increased as the filling extends, uninterrupted, to cover about 1/3 of the tooth circumference. This may have caused plastic deformation of the composite filling as many authors reported a significant decrease in margin quality after thermo-mechanical stresses [17, 48] without affecting internal adaptation [48] which suggests the deformation of the cervical margin of the tooth/restoration which is increased in this case due to the extended length of composite margin. On top of that, connection of the mesial and buccal fillings could have compromised the resistance of the composite filling as it is only surrounded by the pulpal (axial) and gingival walls whereas the fillings in the other groups are surrounded from 2 more directions; bucally and lingually.

The second null hypothesis was the consistency of the vertical margin gap distance of the crown if the relocated margin was placed on direct composite, indirect composite or flowable composite was partially rejected. Flowable composite showed higher gap distance than the nano hybrid composite which could be due to that flowable composites, which exhibit high contraction stress during polymerization due to the small amount of filler content, may not be sufficiently resistant to deformation under load [49] nevertheless, there was no statistical significant difference in the vertical margin gap distances among direct composite and flowable composite as CMR materials.

These results agreed with ***Spreafico et al (2016)*** [47] who evaluated the effect of (CMR) using composite resin on the marginal quality of crowns and found that the type of composite resin did not affect the marginal adaptation of the tested types of crowns. These results were also confirmed by ***Zaruba et al (2013)*** [48] where they assessed the effect of a proximal margin elevation technique on marginal adaptation of ceramic inlays in which they concluded that margin relocation technique with composite filling in the proximal box before insertion of a ceramic inlay, results in marginal integrities not different from margins of ceramic inlays placed in dentin. Another study conducted by ***Sandoval et al (2015)*** [50] evaluated the influence of different composite bases on marginal and internal adaptation of class II CAD/CAM ceramic inlays and denoted that, results did not reveal any significant difference among groups under evaluation. Furthermore, a clinical study conducted by ***Bresser et al (2019)*** [20] in which two hundred indirect restorations with cervical margin relocation in the posterior region with twelve years performance in the oral cavity were evaluated, and the authors reported that, an overall survival rate was significantly better when compared to data from the literature evaluating indirect restorations without CMR [51-54].

On the other hand, ***Frankenberger et al (2013)*** [17] reported that luting of ceramic restorations directly to dentin leads to higher percentages of gap-free margins, when compared to bonding of indirect restorations to CMR.

In the present investigation, the highest mean value of marginal gap distance was found in indirect composite restorations where there was no significant difference between indirect composite and flowable composite; albeit, a significant difference was present between indirect composite and direct composite as CMR materials. This difference can be explained by the presence of the adhesive resin cement or the composite inlay cementation procedure as the composite material was the same for the two groups. The fact that indirect restorations were developed to overcome the polymerization shrinkage exhibited by direct application of composites so they are precured and fully set before insertion in the cavity leaving little amount of free radicles to establish a strong bond with the resin cement at the crown/restoration interface, as those free radicles were already consumed during luting the restoration to the prepared cavity.

Microleakage caused by microscopic openings at the tooth/restoration interface, is considered a major cause of restoration failure [55]. The efficiency of the restoration seal have been assessed frequently by microleakage tests which are challenged of their inability to reproduce the oral environment in an in vitro setting and their outcomes are unpredictable due to different test approaches [56].

The third null hypothesis suggested that there was no difference in the microleakage at the tooth/resin interface regardless of the technique or the material of filling was rejected. The results obtained by this study showed significantly low marginal adaptation of flowable composite than other groups which could be attributed to the fact that although flowable composites are simply syringed into the cavity they are sometimes difficult to manipulate because of their stickiness also, after injection of the material, the syringe tip may trap some air in the restoration upon its removal [57]. This result was confirmed by ***Tayel et al (2016)*** [58] who reported that flowable composite showed the least capacity for sealing and obtained the highest microleakage score among the four different composite viscosities used. Moreover, ***Moazzami et al (2014)*** [59] reported the same results regarding flowable composite and justified the results by the fact that the gingival floor of the proximal box is the furthest from the light source in class II cavity preparation in dentin/cementum. Light intensity is dramatically decreased when the distance between the light-curing tip and the resin surface is >2 mm prohibiting adequate polymerization of resin composite materials [60]**.** Unconverted double bonds might be increased by the lower degree of monomer conversion, rendering the resin more prone to degradation by premature breakdown at the tooth-restoration interface [61]***,*** thus leading greater leakage value [60]. These results were also confirmed by ***Poggio et al (2013)*** [62] who tested the sealing ability of Class II composite restorations using different viscosities and techniques and reported that a possible explanation might be due to the lower monomer and higher filler content presented in nano hybrid composites.

On the other hand, ***Gowda et al (2015)***[63] evaluated flowable composite and resin modified glass ionomer (RMGI) in terms of microleakage and found that specimens with flowable composite liner showed statistically better seal compared to RMGI liner group and contributed their results to the fact that there is minimal internal porosities incorporated within the material. On top of that, the intimate fit of flowable composite to the prepared cavity provides a profound bond with the microstructural defects of the cavity preparation, moreover, flowable composite with a low modulus of elasticity and/or surface tension and increased flexibility would have rearranged the stresses accompanied with polymerization shrinkage and retained bond integrity to tooth structure [64].

Boruziniat et al (2016) [65] reported that application of flowable composite on the gingival margin as a liner did not reduce microleakage or improve clinical performance of indirect restorations. But ***Sandoval M et al (2015)*** [50] reported that cervical dentin adaptation of indirect restorations lined by flowable composite was better than restorations without lining with no significant difference between them. ***Hernandes et al (2014)*** [66] suggested that flowable composite thickness under indirect restorations has an important role in gap distance as they concluded that a liner of 2mm thickness showed more gap distance than liners of 1mm and 0.5mm thicknesses which confirms the results of the current study.

Regarding the present study, cervical dentin adaptation of indirect restorations was numerically inferior to that related to the nano hybrid composite with no significant differences between them. As suggested by the authors, this result could be attributed to the type of resin cement used in the present investigation, Multilink Speed, which is a self-adhesive cement that contains an adhesive monomer with a phosphoric acid group which is designed to react with the calcium ions of the dental hard tissues and produce a bond with the tooth structure, as claimed by the manufacturers [67]. This adhesion mechanism beside the fact that cementum is a complex substrate where its outer layer is hypomineralized and hyperorganic, which does not provide microretention for the adhesive materials even after acid-etching[68]. Resulted in the inferior performance of the indirect composite regarding marginal adaptation to cementum margins.

Some studies contradicted this finding and have reported that indirect inlay composite restorations result in less microleakage than direct composite resins[69,70]. These findings could be due to polymerization induced shrinkage inherent to the composite resin is greater when the resin is directly inserted in the cavity than the shrinkage of the resinous cement layer used to fix the indirect inlay. Additionally, the shrinkage of the resin cement is balanced by the distortion of the cavity walls. ***Liberman et al (1997)*** [71] concluded that the indirect procedure resulted in a significantly reduced microleakage when compared to that produced by the direct technique. ***Alavi and Kianimanesh (2002)***[72] concluded that proper application of bonding agents leaves the indirect technique in Class V cavities with no clear advantage, but when large Class II cavities are restored, the effect of the shrinkage stress at the cervical margin placed in dentin-cementum is most significant.

Limited researches that discuss the effect of CMR on ETT restored with full coverage restorations are published, nevertheless, the mean vertical marginal gap distance for all the groups was found to be within the clinically acceptable range of 0-120 μm [73-76].

It should be noted that this study was performed under vertical forces, therefore, it is of value to optimize the direction of forces in the clinical practice to obtain favorable results recommended by this study. This was highlighted by some researches which suggested that more important factors are to be considered in the case of the restoration of ETT posterior teeth; the type of occlusion, whether it is group function or canine-guided, as group function increases the lateral component of forces on posterior teeth. Decreasing the cusp height will significantly affect the type and direction of the forces applied to each tooth [77-79].

The use of extracted teeth is a limitation of this research. Further clinical investigations are needed to validate the results obtained from this study.

CONCLUSIONS

The following can be concluded from the outcomes of this study:

1. The use of CMR with single or multiple narrow cavities is more favorable than with wide cavities.
2. Direct nano-hybrid composite or flowable composite can be used with CMR under full-coverage crowns.
3. CMR is a logical option in teeth with deep proximal cavities that needs to be crowned.

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