Marginal Adaptation Assessment of Different Post-Obturation Restorative Materials (In-Vitro Study)

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ABSTRACT:

Purpose: The aim of this study was to evaluate the marginal adaptation of two different post-obturation restorative materials of premolars with mesio-oclussal-distal MOD cavity.

Materials and Methods: Twenty sound premolars received root canal treatment and MOD cavity. All teeth were divided into 2 groups (n=10). GpA: (Ribbond, polyethylene fiber; USA) inserted in short fiber reinforced resin composite, Ever x Posterior; Japan) followed by nanohybrid Filtek Z250xt; 3M,USA); GpB: (fiber post and core with nanohybrid Filtek Z250xt;3M,USA) then CAD/CAM Emax crown. Marginal adaptation was assessed before and after thermocycling using Stereomicroscope. All teeth were subjected to 5000 cycle's equivalents to 6 months. Dwell times were 25 s. in each water bath with a lag time 10 s. The low-temperature point was 5 0C. The high temperature point was 55 0C. Data were collected and analyzed using one-way analysis of variance was performed followed by Tukey's post-hoc test if showed significance between both groups.

Results: Marginal Adaptation was significantly higher before and after thermocycling for GpA (before: 38.12±2.85 µm, after: 42.55±1.19 µm) than GpB (before: 55.54±1.17 µm, after: 68.24±9.78 µm).

Conclusions: Restored teeth with this conservative approach were able to bear thermocycling. The integration of both fiber reinforced resin composite with ribbond had positive effect on marginal adaptation.

Keywords: marginal adaptation, fiber reinforced composite, root canal treated teeth, ribbond

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Introduction:

Restoring an endodontically treated tooth "ETT" has always been a challenge, as endodontic therapy is an invasive procedure done usually after caries invades and destruct dental hard tissues Furthermore, access cavity preparation that includes removal of the arched roof of the pulp chamber [(1)] and with the combination of a MOD (Mesio-Occlissal-Distal) cavity, results in losing about 63% of tooth integrity [(2)]. This makes "ETT" prone to fracture and can't withstand masticatory forces and no longer perform aesthetics neither mechanical function [(3)].

For many years, post / core and crown restorations have been the gold standard for such cases [(4)], as they have shown a superior character compared to direct composite, overlays, and endo-crowns [(5)]. This includes superior retention and support to remaining tooth structure, highest fracture resistance, least microleakage and being financially economic as well as timesaving since they require only one appointment [(5)].

As conservatism is the aim, Indirect restorations have been used recently by CAD/CAM [(3)]. They're preferred for saving tooth structure as they need limited dentine removal around the roots, reduce tooth weakening, and result in reduced procedural errors [(3,4)]. Although they're conservatism is considered a double-edged sword as they cannot withstand microleakage by the used bonding techniques [(6)].

Recent studies and technology show superior bonding techniques and fracture resistance, achieving better marginal adaptation that can resist microleakage and masticatory forces[(1,7,8)], so polyethylene fibers "ribbond" was introduced to our industry to preserve root canal system and support residual tooth structure[(1,4,8)]. The present study was conducted to compare marginal adaptation of ETT in MOD cavity restored with: post and core with crown against direct reinforced composite with ribbond insert, which we will discuss in our study.

Materials & Methods:

The study proposal was reviewed and approved by the Research Ethics Committees (REC) of the Faculty of Dentistry, Ahram Canadian University, Egypt, on 29/11/2022. With approval number IRB0001289≠29.

Twenty freshly extracted permanent human maxillary premolars were selected. Each tooth was examined for the presence of abrasions, fractures, cavities, restorations and excluded. Teeth were stored in 0.1% thymol solutions and cleaned of debris using a hand scaler then placed in deionized water for 24 h before starting the experiment. [(9)] Teeth were randomly divided into two groups of 10 teeth.

Group A) was to receive polyethylene fiber (Ribbond) and glass fiber reinforced resin composite restorations (Ever-x resin composite); whilst Group B) re-presents teeth that are to receive posts and then core followed by CAD/CAM crown.

The teeth had their roots embedded in cylindrical polymerization of vinyl chloride PVC ring (1. 4 × 2 cm) using an auto polymerizing acrylic resin (Acrostone, Cairo, Egypt), up to 3 mm below the cemento-enamel junction (C.E.J). To mimic the periodontium, the roots of the teeth were demarcated 3 mm below CEJ using a red pencil, then dipped into melted wax to produce a 2mm to 3mm layer approximately equal to the average thickness of the periodontal ligament. [10]

Cavity Preparation:

Each tooth was given a standardized class ll MOD cavity that has a 2.0 mm gingival cavosurface border above the cement-enamel junction using a cylindrical diamond bur (Meisinger, Germany). Using a calliper, the buccolingual width of each cavity was found to be half of the buccolingual distance. The cavities had a level floor, no proximal step, and a depth of 4.0 mm. The facial and palatal walls of the cavity were prepared parallel to one another, and all internal line angles were rounded [3,6].

Root canal treatment

The same operator prepared endodontic access cavities in all specimens. Using a hybrid method, the root canal preparation was carried out using K files (Mani NiTi K files). A digital x-ray was used to assess the working length after the insertion of NiTi files. (Mani NiTi K File) A No.40 master apical file was used and a 1mm steps step-back procedure was performed until file No.60. Sodium hypochlorite (5%, jk sodium hypochlorite solution) is used after each file to rinse the canal and paper points are used to dry the canal. The obturation process was done using No.40 gutta percha points (Meta Biomed), accessory points (Meta Biomed), and sealer (AD Seal Meta Biomed). The distance between the radiographic apex and root canal filling was measured using a digital x-ray (SkyDent, Slovakia). Extra gutta-percha was eliminated with a heated tool, and the coronal portion was compacted vertically with a plunger and then cavity was cleaned with cotton dipped in alcohol.

The self-etching bonding (All Bond; BISCO, USA) was applied to the cavities according to the manufacturer’s instructions. The polymerization of the bonding agent was performed with a light-emitting diode (Woodpecker, RTA) at a minimum intensity of 1,200 mW/cm2. The cavity floor was covered with a 1 mm layer of Nano Hybrid Flowable Dental Composite Resin (Nexcomp Flow; META BIOMED). The coronal restorations were completed as indicated for each group. [(1)]

Group A (Ribbond+ Ever-x resin composite):

A piece of Ribbond ULTRA (Ribbond; USA) (~5 mm long, 2 mm wide) was prepared. Then the strip was saturated with bonding agent (Gluma Universal) and placed in the flowable resin from the buccal to the lingual direction without touching the enamel margins. After light-curing for 20s with an LED, the remaining cavity space was restored with GC ever X Posterior (fiber reinforced resin composite) using an oblique incremental technique (a maximum of 2 mm of resin was placed in each turn, and each increment was light cured for 20 s). Last layer a micro-hybrid composite resin (Filtek Z 250, 3M ESPE Dental Products, USA) was applied. Finishing and polishing was done, using discs (Soflex;3M ESPE, Germany). [(1)]

Group B (Post and Core):

Post preparation:

For cylinder-conical size M glass fiber post, a 10 mm deep preparation was made with proper drills (Piezo reamers drills) using a low-speed contra-angle handpiece (Apple, China). Rinsing canals was done with tap water then dried using paper points. An adhesive system (Dentkist Charm Supercem Self-adhesive resin) was applied following the instructions of the manufacturer. Paper points (Meta Biomed) were used to apply the bonding agent (Bisco Bond), a dual curing resin luting material (SuperCem universal self-etch, Dentkist) in a ratio of 1:1 base to catalyst was mixed that was introduced and applied to the surface of the root canal using No.25 Lentulo spiral. (Mani). A thin film of the bond was used to cover the post fiber, then inserted in the root canal that had been already filled was a luting composite. For the core build-up, a fine hybrid composite resin (Filtek Z250 XT Nano hybrid universal restorative, 3M ESPE) was used with the increment-by-increment method. Also, Finishing and polishing was done, using discs (Soflex; 3M ESPE, Germany). [(4)] All procedures were done by the same dentist.

Teeth Preparation for crown:

Uniform teeth preparations were performed which included: axial reduction of about 1.5 mm, deep chamfer finish line of 1.0 mm depth, planar occlusal reduction with 5mm occluso-gingival height and 6^0 of convergence.[(1)]

Crown fabrication

Omnicam intra oral scanner was used to scan all the prepared teeth. The CEREC 3D software (version 4.2, Sirona Dental Systems Gmb Bensheim, Germany) was used for designing the crown restorations. All restorations (IPS e.max CAD blocks) were milled with 4-axis wet milling and grinding machine MCXL (Dentsply Siron Bensheim, Germany)

Crown placement and cementation:

All crowns were etched with buffered hydrofluoric acid gel "Bisco; porcelain etchant (9.5%) Hydroflouric acid". After etching, the crowns were treated with a silane coupling agent "Bisco; porcelain prime". Prepared teeth were etched using phosphoric acid to improve the bonding with restoration meticulously, around the finish line which composes solely of enamel. Then, a self-etching bond "Bisco; all bond" was applied to all preparations and photo-polymerized for 20 secs. Then, dual cure self-adhesive cement "Bisco; biscem" was used for final cementation. The crowns were weighed down and the excess cement was removed afterwards. (1)

<u>Marginal gap distance:</u>

Each specimen was photographed using Stereomicroscope (X500 Digital Microscope with a built-in camera) before and after thermos-cycling:

Technique; the images were taken with the following image acquisition system;

1) U500x Digital Microscope (***Guangdong, China***) with 3 Mega Pixels of resolution, placed vertically at a distance of 2.5 cm from the samples. The angle between the axis of the lens and the sources of illumination is approximately 90º.
2) Illumination was achieved with 8 LED lamps (Adjustable by Control Wheel), with a color index close to 95 %. The images were taken at maximum resolution and connected with compatible personal computer using a fixed magnification of 40X.The images were recorded with a resolution of 1280 × 1024 pixels per image.
3) A ***digital image analysis*** system (Image J 1.43U, National Institute of Health, USA) was used to measure and evaluate the gap width. Within the Image J software, all limits, sizes, frames and measured parameters are expressed in pixels. Therefore, system calibration was done to convert the pixels into absolute real-world units.
4) ***Calibration*** was made by comparing an object of known size (a ruler in this study) with a scale generated by the Image J software. Shots of the margins were taken for each specimen for all surfaces. Then morphometric measurements were done for each shot [4 equidistant landmarks along the circumference for each surface. Measurement at each point was repeated

three times. Then the data obtained were collected and tabulated

Thermomechanical cycling:

All teeth were subjected to artificial aging in a masticatory simulator (Robota automated thermal cycle; BILGE, Turkey) In this study the number of cycles used was 5000 cycle's equivalent to 6 months. Dwell times were 25 s. in each water bath with a lag time 10 s. The low-temperature point was 5 0C). The high temperature point was 55 0C. [11]

Statistical Analysis:

Data were presented as the mean and standard deviation. After homogeneity of variance and normal distribution of errors had been confirmed, 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 (restoration type and ageing). Sample size (n=10) 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. 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:

Vertical marginal gap (µm)

Descriptive statistics of vertical marginal gap (µm) 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 (1).**

Before thermal aging; it was found that the higher marginal gap mean value recorded for ***GpB*** (55.54±1.17 µm) than ***GPA*** (38.12±2.85 µm) and this was statistically *significant* as verified by one way ANOVA followed by pair-wise Tukey's post-hoc tests (p =<0.0001<0.05). **Table (1)** and **figure (1).**

After thermal aging; it was found that the higher marginal gap mean value recorded for ***GPB*** (68.24±9.78 µm) than ***GPA*** r (42.55±1.19 µm) and this was statistically *significant* as evidenced by one way ANOVA test (p =0.0013<0.05). **table (1) and figure (1).**

Before vs. after thermo-cycling; there was statistically *significant* ($p < 0.05$) difference within each group as proved by student t-test where marginal gap mean value after thermal aging was higher than before. **Table (1)** and **figure (1,2,3,4,5)**.

Total effect of restoration group on vertical marginal gap mean values

Regardless to thermo-cycling, totally it was found that the difference between both groups mean values was *statistically* *significant* (p=<0.0001 < 0.05) as verified by two-way ANOVA test where (*GrB> GrA).* Table (1) and figure (1)

Effect of thermo-cycling on marginal gap

Irrespective of restoration group, it was found that thermo-cycling *significantly* affected marginal gap mean values (p=0.0004<0.05) as demonstrated by two-way ANOVA test. Table (1) and figure (1)

Table (1) Comparison of marginal gap results (Mean values ±SDs) between both groups before and after thermal aging:

Variable		***Thermal aging***								
		Before				***After***				***Statistics***
		Mean	***± SD***	***95% CI***		***Mean***	***± SD***	***95% CI***		***t-test***
				Low	***High***			***Low***	***High***	***P value***
Main group	***Gr_A***	**38.12^{A}**	**2.85**	**35.48**	**40.75**	**42.55^{B}**	**1.19**	**41.45**	**43.65**	**0.0025***
	GrB	**55.54^{B}**	**1.17**	**54.46**	**56.63**	**68.24^{A}**	**9.78**	**59.19**	**77.29**	**0.0052***
Statistics	***P value***	**<0.0001***				**<0.0001***				

Different letters in same column indicating significant between groups (p<0.05) *; significant (p<0.05) ns; non-significant (p>0.05)

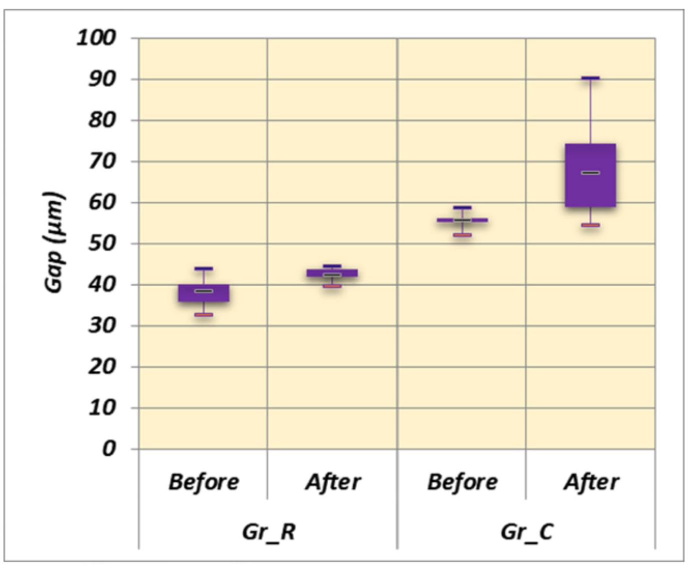

Figure (1) Box plot chart comparing vertical marginal gap values between all groups before and after thermal aging

Figure (2): Digital microscopic image for marginal gap before thermocycling/ crown

Figure (3): Digital microscopic image for marginal gap after thermocycling/crown

Figure (4): Digital microscopic image for marginal gap before thermocycling/Ribbond

Figure (5): Digital microscopic image for marginal gap after thermocycling/Ribbond

Discussion:

After emergence of biomimetic view point, the conversation and preservation of teeth structures are fundamental in maintain the balances between mechanical, biological, adhesive, functional and esthetic parameter. Preservation of coronal tissues and avoiding invasive endodontic procedure are beneficial, because these ways ensure the biomechanical balance and long term performance of restored tooth. (3)

Marginal adaptation is the degree of proximity or interlocking of filling material to the walls and especially the margins as it is always a sensitive region. Although it's what we seek in restoration as achieving, it gives success in many aspects from increasing its durability, longevity and decreasing micro-leakage hence the recurrent caries.

Clinical longevity of any restoration whether is direct or indirect depends on a good marginal adaptation, so poor marginal adaption exposes weakened endodontically treated tooth to oral environment, rendering restoration susceptible to plaque retention and microleakage, this infiltration leads to recurrent caries, periodontal disease and finally restoration failure. (12) This kind of failure is considered one of the main reasons for survival of root canal treated teeth. (4, 13)

However total marginal adaption is rarely reached clinically and there has to be some kind of gap. (12) Our aim to maintain it at minimum to exclude in the future, invasive full coverage of endodnotically treated teeth. Artificial aging is a crucial part of an in vitro study as repetitive stresses during mastication may lead to subcritical crack growth in examined restorative materials. All specimens were subjected to dynamic loading and thermal cycling to investigate specimen behavior under clinically approximated conditions (14)

Some studies suggested that because of the mechanical properties of ceramic restorations, they have the ability to strengthen the tooth structure. (3) Moreover, it was mentioned that teeth with crown restoration had a six-fold higher success rate than teeth with direct restorations. (3) IPS e.max CAD is a lithium-disilicate system that widely used since it proposes optimum aesthetics and high fracture resistance. Also, fabricating ceramic crowns for posterior teeth offer higher survival rates over 5 years among cemented crowns. (15) It was mentioned that it has better stability of marginal adaption among indirect restorations. (16) This owed to crystallization firing has a positive effect on the marginal gap on this kind of crowns. (16)

Increased in marginal gap for CAD/CAM group after thermocycling, was due to the rupture of the bond between luting agent and the tooth had occurred. The cause of this rupture was due to difference in thermal expansion between tooth, luting agent and ceramic, cycling of all ceramics between high and low temperature. In addition to temperature cycling causes percolation in the gap created at dentin interface and luting agent. (16)

A short fiber-reinforced composite (FRC) (ever X Posterior) was launched as a dentine-replacing materials. Combination of a resin matrix, short E-glass fibers and inorganic particulate fillers were added. The polymer matrix called semi-interpenetrating polymer network (semi-IPN), which provides good bonding property and increases the toughness of composite. This polymer matrix was formed by resin matrix that cross-linked bis-GMA, TEGDMA and linear PMMA. The short fiber composite resin has also proved to control the polymerization shrinkage stress by fiber orientation and, thus, marginal microleakage was reduced compared with conventional composite. (17)

On the other hand, polyethylene fiber ribbon was referred as a leno-weave ultrahigh-modulus polyethylene fiber. Its composition and technique of application by soaking in bonding agent before they were mixed with resin composite, improved significantly the fiber- composite matrix. This method has been shown to overcome the shortcomings of traditional microleakage assay methods. (18)

The results of the present study indicated that incorporating polyethylene fibers into short fibers reinforced composite resin matrix was significantly better regarding the marginal adaptation in comparison to the crown group before and after thermocycling. (4,13, 16) This is may be due to gaining the mentioned benefits of both materials against lithium disilicate crown. Onlay Thomas Hitz, in 2010 found non- significant difference between both groups before thermocycling. This is may be due to using only glass fiber (Vectris Frame) as a source of enforcement supporting Traditional resin composite (Tetric Ceram).(13)

After thermocycling phase, (Ribbond/ short fiber reinforced Group) showed significantly increased in marginal gap but still lower significantly than crown group. This is may be due to, during the placement of ever X Posterior, the fibers orientate into a horizontal plane within the cavity. This produces strong adhesion between the resin and the silanated fibers, the direction of the fibers minimizes shrinkage in the horizontal plane after placement though vertical shrinkage does take place. [19] While the polyethylene fiber (Ribbond) imbedded in the composite material can decreases the volumetric contraction of composites. However the results of this study didn't support the stability of marginal adaptation and significant increase in marginal gap was seen. A study was found that addition of polyethylene fiber in composite resin material didn't improve marginal adaptation. They explained the cause may be due to presence of affected dentine in gingival margin. [9]

Conclusions: Within the limitation of this vitro study on intracoronal restorations in endodontically treated premolars with mesio-occlusal-distal Class II cavities, with respect to marginal adaptation, fiber reinforced resin composite showed better performance than eMax CAD/CAM crown.

Recommendations: Promising results motivate toward more vitro and clinical studies regarding using this conservative model to replace other indirect restorations (Onlay/Endocrown)

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