



Research Article

## Apatite Forming Ability and Gingival Marginal Adaptation of Two Bioactive Bulkfill Composite Restorative Materials (An in vitro comparative study)

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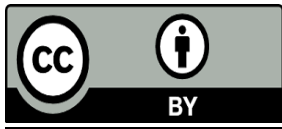
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### Abstract

**Aims:** The present study aimed to assess the apatite-forming ability and marginal adaptation of two bioactive bulkfill restorative materials in Cl. II cavities after storage in phosphate-buffered saline (PBS).

**Materials and Methods:** Sixteen sound molars with nearly equivalent occlusal size were molded into a PVC tube, then divided into four groups (n=4) based on composite material types. Each tooth received two separate MO and DO cavity preparations, cavity restorations, and thermocycling, then stored for 28 days in PBS. After that, all the teeth samples were sent for FESEM/EDX analyses. Statistical analyses were performed using One-Way ANOVA and Duncan's Multiple Range test to evaluate and compare the results at a 5% significant level.

**Result:** According to the study, there was a statistically significant difference at ( $P \leq 0.05$ ) among the groups in terms of gap width formation in  $\mu\text{m}$  at restorative materials-gingival enamel margin interfaces. Group B: Ever X Posterior represented the highest mean of gap width ( $13.05 \pm 3.68$ ), followed by group D: Predicta bioactive ( $7.86 \pm 1.22$ ) and group C: Cention N ( $7.50 \pm 1.09$ ), while group A: Tetric powerFill represented the lowest mean of gap width ( $6.50 \pm 1.61$ ). The FESEM images for bioactive materials represented the apatite deposition, and these results were confirmed with the EDX compositional elements analytical results.

**Conclusion:** The gingival marginal adaptation of Cl. II cavities can be affected by the composition and the properties of the composite materials used. The bioactive restorative materials are considered promising materials with clinical beneficial effect.

**Keywords:** Predicta bulk bioactive, Cention N, hydroxyapatite, Marginal adaptation.

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## INTRODUCTION

The introduction of bulkfill composites for the restoration of posterior teeth simplified the restorative procedure and overcame the drawbacks of the layering technique (1,2,3). Marginal adaptation and recurrent caries are the most common difficulties associated with composite restoration that considered important properties in assessing the success or failure of restorations (4,5).

Class II composite restorations appear to be more prone to the development of restoration failure compared to class I restorations, due to limited access, difficulty in isolation, and the material's limitation of polymerization shrinkage (6,7). Actually, the common site in danger of bonding failure and microleakage is the gingival margin of a class II restoration (8-10).

Since the composite-tooth interface is a weak link of the restoration, efforts have been devoted to developing materials with specific interaction with dental tissue (5). Currently, the dental materials have changed the behavior from being a passive biomaterial to having a positive interaction with tooth structure (11,12).

The bioactive restorative materials with their compositions that allowed the release of calcium, phosphate, and fluoride are supposed to precipitate a hydroxyapatite layer, induce mineralization, and, as a result, reduce micro gaps along the tooth-restoration interface (13). In 2016, the Alkasite restorative material, which has been developed as a hybrid group of composites" introduced to the market (14). It is a novel class of filling material that releases ions such as fluoride, calcium, and hydroxide, permitting pH levels to be controlled, which helps to prevent enamel demineralization and stimulate remineralization, which is considered a subset of bioactive material(15,16).

The Predicta bioactive was introduced to the market as a bulk bioactive restoration. According to the manufacturer's claim, its bioactive property provides a strong bond with the tooth by stimulating mineral apatite formation and remineralization that leads to sealing the tooth-restoration interfacial microgaps and protecting against microleakage (17,18). Nowadays, there are many questions about

the bioactivity of restorative materials and their ability to adequately seal the marginal gaps. Therefore, the goals of the current study are to estimate the hydroxyapatite-forming ability and measure the marginal adaptation of four types of bulkfill composite restorative materials: Tetric PowerFill, ever X Posterior, Cention N, and Predicta bioactive after storage in phosphate-buffered saline (PBS) for 28 days.

## **MATERIALS AND METHODS**

### **Ethical Approval**

An ethical approval was received from the "Research Ethics Committee" at the Faculty of Dentistry, Mosul University, Iraq, at clearance number (REC reference No. **UoM. Dent/H.DM.4/23**) before starting the investigation.

### **Sample collection and preparation**

Sixteen human nearly equivalent occlusal size molars extracted for orthodontic purposes from patients between 20-30 were utilized in this investigation (18,19). They were scaled with a scaler to remove any calculus and periodontal tissue appurtenances, then cleaned with eugenol-free pumice. The teeth were examined under the stereomicroscope at 10X magnification to exclude any defective teeth (20,21). The teeth were then disinfected using (0.1% thymol solution) for two weeks, and after that kept inside a screw-capped glass container filled with distilled water at room temperature ( $23\pm 2^{\circ}\text{C}$ ) until the next step (22).

### **Cavity preparation and sample grouping**

Each tooth was mounted in a polyvinylchloride tube (PVC), showing 3 mm below the CEJ with the aid of the surveyor in such a way that the long axis of the tooth was parallel to the long axis of the PVC tube (23,24). Each cusp with a slight height than other cusps was reduced occlusally within the enamel, and hence provides a nearly flat surface to standardize the position of light curing unit and to stabilize the frame for cavity preparation (25-27). Each tooth prepared with two separated Class II proximal box cavities (mesially and distally) located 1mm coronal to CEJ with mesio-distal width: 1.5 mm, bucco-lingual width: 2 mm, occluso-gingival: 4 mm(28,29), and

they were prepared utilizing a high-speed, air/water spray and a parallel-sided (1.2 mm) diameter diamond fissure bur with the aid of standardized metal frame and modified dental surveyor to standardize the cavity preparation (30). A digital caliper was used to check the dimensions of all the cavities. The samples were then assigned into four major groups (n=4) in accordance with the restorative material types as follows:

**Group A:** Teeth samples were restored with Tetric PowerFill restoration.

**Group B:** Teeth samples were restored with Ever X Posterior restoration.

**Group C:** Teeth samples were restored with Cention N restoration.

**Group D:** Teeth samples were restored with Predicta bioactive restoration.

#### **Cavity restoration**

Each cavity received etching, bonding, and restoration. The etching step was performed using a selective etching technique for enamel with phosphoric acid 37% N-etch for 15 sec, and then gently air dried after being washed. Bonding step was being done by applying G-Premio bond using a disposable brush to the full cavity, wiped for 20 sec, then air dried for approximately 5 sec. After that, in accordance with the manufacturer's directions, an LED light with an output intensity of 1000 mW/cm<sup>2</sup> at 395-480 nm was used to cure the adhesive for 10 sec.

Finally, the restorative procedure for each group was carried out in accordance with the manufacturer's recommendations for their restorative material. To provide the required proximal anatomic contour, a polyvinyl siloxane matrix was used for securing each tooth (31,32). Each bulkfill composite was applied as one 4 mm increment, and restorations were exposed to irradiation for 20 sec from the occlusal, then additional curing was applied after removal of the matrix from the buccal and lingual surfaces, and then finished and polished. The teeth samples were then kept in the incubator for 24 hours at a temperature of  $37 \pm 2$  °C and humidity 95% to complete polymerization (33). The materials used in this study are shown in (Table 1).

**Table 1:** Materials used in the current study, batch number, and composition.

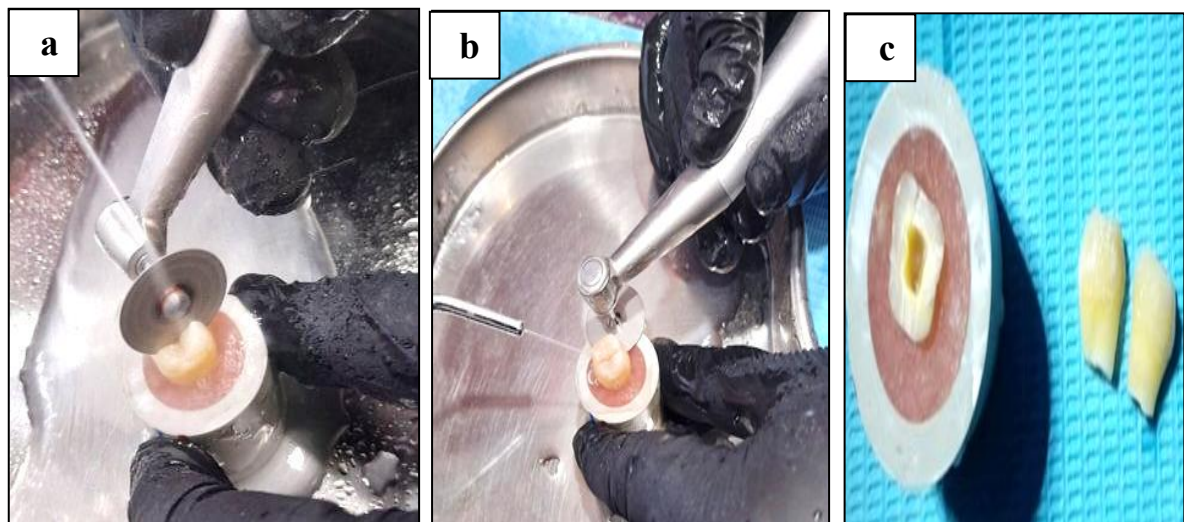
Materials	Batch No.	Composition
Tetric Power Fill Ivoclar viva-dent, Liechtenstein	Z02SZY	Monomer: Bis-GMA, UDMA, Bis-EMA, DCP, AFCT agent ( $\beta$ -allyl sulfone), propoxylated bisphenol A dimethacrylate. Photoinitiator: Ivocerin+ CQ/amine + Lucirin TPO. Filler: copolymer (Isofiller), Ba-Al-Silicate glass, mixed oxide (SiO <sub>2</sub> /ZrO <sub>2</sub> ), Ytterbium trifluoride.
ever X Posterior GC Corp., Japan	2205131	Monomer: TEGDMA, Bis-GMA, PMMA. Filler: barium borosilicate glass filler, E-glass fibers 1-2 mm length. Photoinitiator: CQ, TPO.
Cention N Ivoclar viva-dent, Liechtenstein	Z03KHZ (powder)	Powder: Isofillers, calcium fluoro-Silicate glass, Barium-aluminum-silicate glass, Ytterbium trifluoride, calcium-Barium-aluminium-fluro-Silicate glass filler, Pigment and initiators.
	Z03K1S (liquid)	Liquid: PEG-400, DCP, UDMA, Aromatic aliphatic-UDMA, DMA Dimethacrylate, hydroxy peroxide, mint flavor, and additives. Photoinitiator: Ivocerin, acyl phosphine oxide.
Predicta bioactive Parkell, USA	2134921349	Monomer: 2-hydroxy ethyl methacrylate, 4-methyl phenylacrylate, 2-propionicacid, 2-methyl, 6-hexanedyl ester poly (oxy-1, 2-ethanedyl), bicyclo (2,2,1) heptane. Initiator: Diphenylphosphine oxide, Di- benzoyl peroxide. Filler: nanofillers, titanium dioxide.
G-Premio BOND GC Corp. Tokyo, Japan	2203021	4-MET, MDTP, 10-MDP, dimethacrylate, thiophosphate monomer, phosphoric acid ester monomer, silicon dioxide, photoinitiator, butylated hydroxytoluene, acetone and water.
N-Etch Vivadent (Ivoclar viva-dent.	Z02V1D	37% Phosphoric-acid gel.

### Thermocycling procedure

All the teeth samples were subjected to 1000 thermal cycles between (5-55) °C  $\pm$  (1) °C with a dwell period of (30 sec)(34,35). After that, the teeth samples were stored in 40 ml PBS-filled containers for 28 days inside the incubator at 37 °C and relative humidity at 95% (36,37). The PBS was renewed every three days to mimic the regular replenishment of bodily fluids throughout the storage period (38).

### Sectioning of the teeth

At the end of 28 days of storage in PBS, the teeth samples from each group were subjected to longitudinal sectioning in bucco-lingual direction to the surface of acrylic and then each half sectioning horizontally below cement-enamel junction near acrylic surface using cutting diamond wheel disc, by this, the crown separated from the root completely and also the crown separated to mesial and distal halves (26,39). Figure (1). Then, the samples were cleaned in an ultrasonic water bath for 3 min and left to dry for 24 hrs (35,40).



**Figure (1):** The tooth sample sectioning procedure: Sectioning in buccolingual direction (a); Sectioning in horizontal direction (b); Tooth sample halves after sectioning (c).

### Preparation of teeth specimens for FESEM/EDX evaluation

The teeth specimens were first attached to aluminum stubs using carbon double-sided tape, and then a thin gold coating was sputtered onto the surface. The FESEM

(TE SCAN MIRA3, France) that was adjusted at 20 kV accelerating voltage and 10 mA was used to evaluate the marginal adaptation at the interface between the restorative materials and the gingival enamel margin by calculating the gap width in  $\mu\text{m}$ . The elemental analysis was investigated by EDX data to calculate the weight percentage of each chemical element and the Ca:P ratio at the interface between the tooth specimen and restoration after storage in PBS (41,16).

### **Marginal gaps calculation**

Gap width is the distance from the restorative material to the gingival enamel at the interface and is calculated in  $\mu\text{m}$ . Gap width was determined by placing two points on each side of the gap (one on the restoration side and the other on the gingival enamel of the box cavity) and measuring this distance with a software program (42). For each sample, the average mean value of gap width was taken (43).

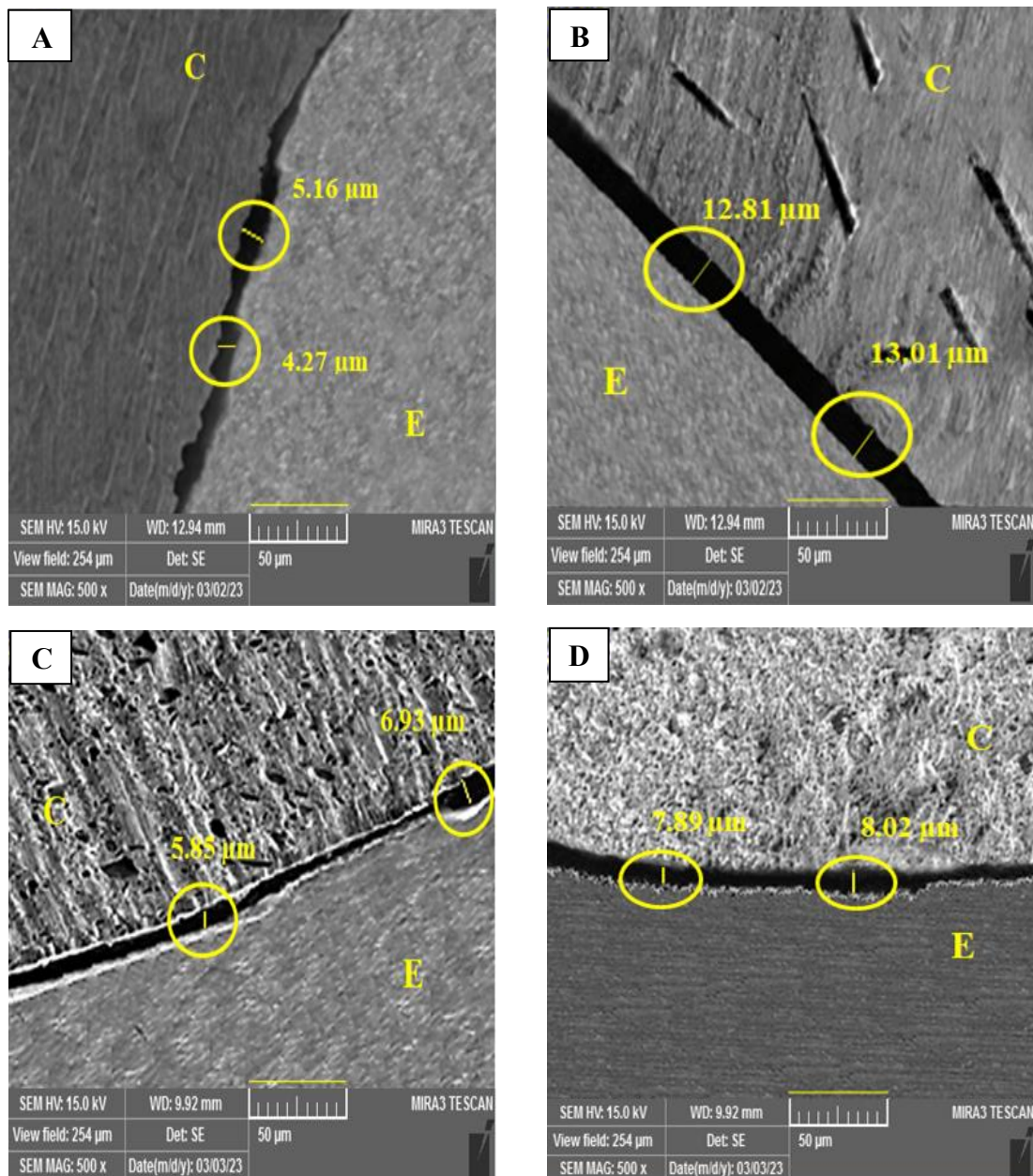
### **Statistical Analysis:**

Statistical analysis was being done using "SPSS software" (SPSS version 20, IBM, USA). The results for the gap width analyses were analyzed by One-way analysis of variance (ANOVA) and Duncan's multiple range tests at 5% significant level.

## **RESULTS**

### **The FESEM analyses of gaps width**

The teeth samples of the stored groups for all restorative materials were examined at 500X utilizing the FESEM device to detect the gap width at the restorative materials- gingival enamel interface in ( $\mu\text{m}$ ). Additionally, the samples were examined at a magnification of 2.00kx to detect the deposition of an appetite layer at the restorative material- gingival enamel interface, as shown in (Figure 2 A-D).



**Figure (2):** The FESEM image at 500X magnification representing the gap at the gingival enamel margin and Tetric PowerFill composite (A); Ever X Posterior (B); Cention N (C); Predicta bioactive (D) after storage in PBS for 28 days. C: Composite, E: Enamel margin.

For the Tetric powerFill group, the mean gap width registered the lowest. While the ever X Posterior after storage recorded the widest gap width values. However, in both materials groups after storage, there was no “crystal-like” deposition that had been noticed at the restorative material-gingival enamel interface.

While both of Cention N and Predicta bioactive groups although the gaps were also present but the FESEM images registered a deposition of apatite layer along the gingival enamel-restoration interfaces. However, these results were further confirmed by the EDX analysis.

### Analysis of gaps width

The descriptive analysis represented by the mean, standard deviation, minimum, and maximum of gap width in ( $\mu\text{m}$ ) at restorative materials-gingival enamel margin interface for all tested groups is represented in Table (2).

**Table (2):** The descriptive analysis of gap width ( $\mu\text{m}$ ) at the restorative material- gingival enamel margin interface for all tested groups.

Groups	N	Mean $\pm$ SD	Minimum	Maximum
A: Tetric powerFill	8	6.50 $\pm$ 1.61	4.27	9.73
B: ever X Posterior	8	13.05 $\pm$ 3.68	8.60	17.55
C: Cention N	8	7.50 $\pm$ 1.09	5.69	8.89
D: Predicta bioactive	8	7.86 $\pm$ 1.22	6.43	10.10

N: Eight cavities per four teeth in each group.

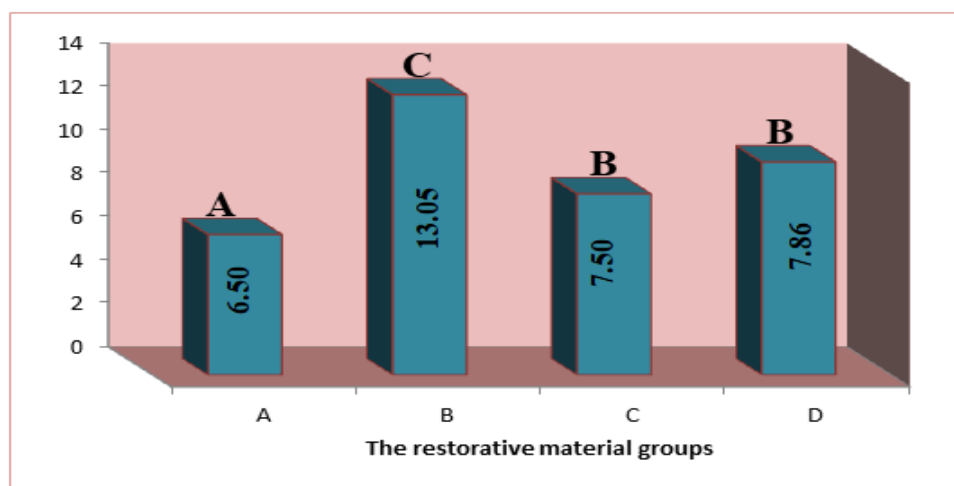
The highest gap width was observed in group B (13.05  $\pm$  3.68), followed by group D (7.86  $\pm$  1.22) and group C (7.50  $\pm$  1.09), respectively, whereas the lowest gap width was observed in group A (6.50  $\pm$  1.61).

One-way (ANOVA) test was performed to identify the significant differences of marginal gap width among composite restorative materials groups at ( $P \leq 0.05$ ) as shown in Table 3. The results indicated that there were highly significant differences between restorative materials groups.

**Table (3):** One-way Analysis of Variance (ANOVA) for different groups of restorative materials

Restorative Materials		Sum of squares	df	Mean square	F	Sig.
A	Between groups	207.403	3	69.134	11.801	0.000
B	Within groups	132.216	28	4.722	14.641	
C						
D	Total	339.619	31			

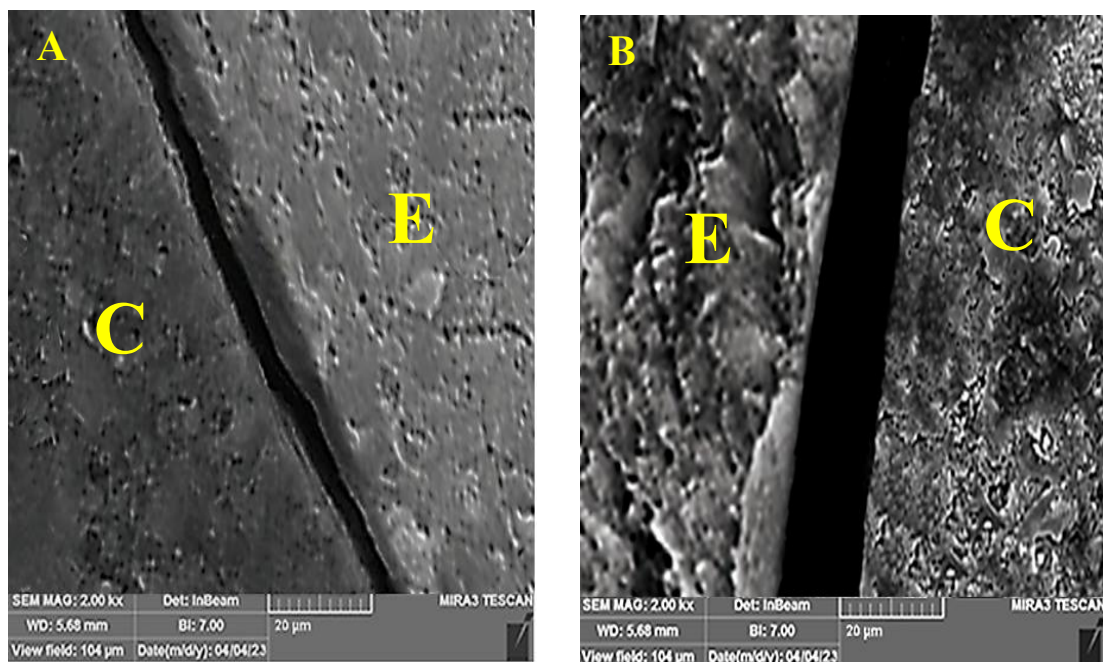
To identify the level of significance that was obtained, Duncan's multiple range test showed that the gap width values of different restorative material types in the order represented graphically in Figure (3).

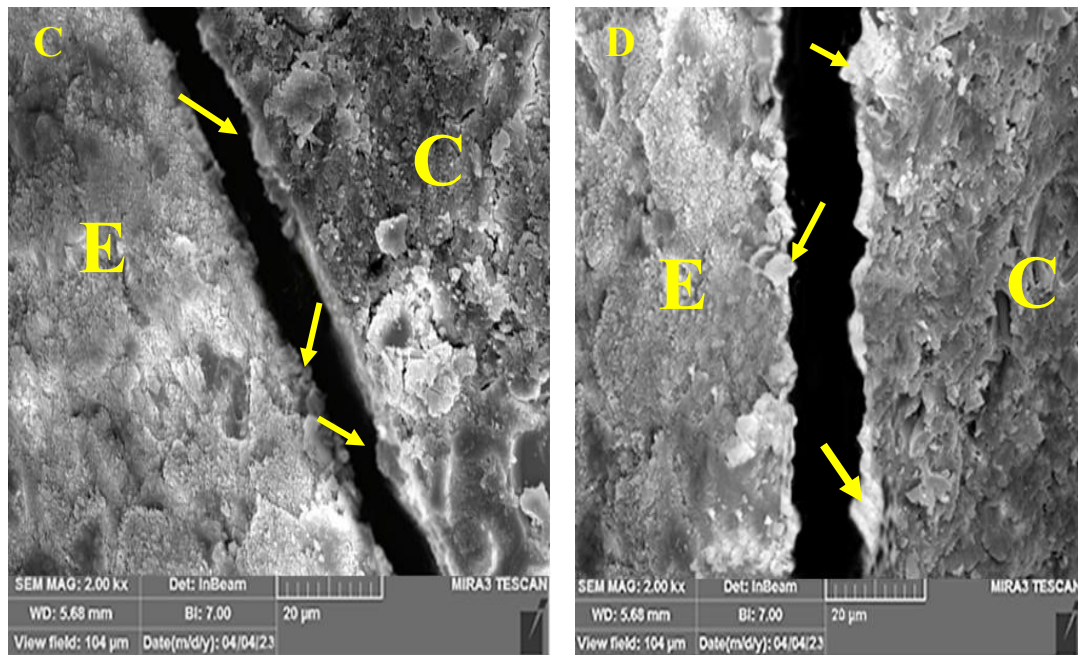


**Figure (3):** Bar-chart represented Duncan's multiple range test for the different values of gaps width with different types of restorative materials, means with different letters have significant differences at ( $P \leq 0.05$ ).

### The EDX analysis

The EDX analysis was done to determine the compositional elements for two regions of interest: the restoration border and the gingival enamel margin adjacent to the restoration. The EDX spectra for composite restorative materials at the interface after storage in PBS for 28 days illustrated that for groups A: Tetric power Fill and group B: ever X Posterior there was no apatite precipitation at the interface since there was no change in the elemental analysis after storage and therefore, the Ca/P ratio was zero for the two groups as shown in Figure 4 A and B respectively. While in group C: Cention N and group D: Predicta bioactive since the EDX spectra registered the peak of phosphorous (P) element after storage in PBS with mean Ca/P ratios which were above that ratio for natural HA (1.67), which as shown in Figures (4 C and D) respectively were about  $(1.8 \pm 0.005)$  for Cention N and  $(1.9 \pm 0.011)$  for Predicta bioactive, this can be indicated the precipitation of apatite and confirm the FESEM analyses.





**Figure (4):** The FESEM image at 2.00kx magnification after storage in PBS for 28 days for Tetric powerFill (A) and ever X Posterior (B), without any crystal-like structure at the restoration-marginal enamel interface, whereas Cention N (C) and Predicta bioactive (D) revealed an HA in the form of a deposit that began to form (yellow arrows) at the borders of the gaps. C: Composite, E: Enamel margin.

Regarding the tooth structure (i.e gingival enamel margin) adjacent to the restorative materials, the EDX spectra mean values for group A and revealed the Ca/p ratio about  $(2.21 \pm 0.03)$  and  $(2.19 \pm 0.03)$  respectively which within the natural HA ratio of enamel  $(2.13 \pm 0.17)$  while for group C and D the ratios were about  $(3.01 \pm 0.07)$  and  $(3.20 \pm 0.03)$  respectively which again indicated the HA layer precipitation as shown in Figure 5 A-D.

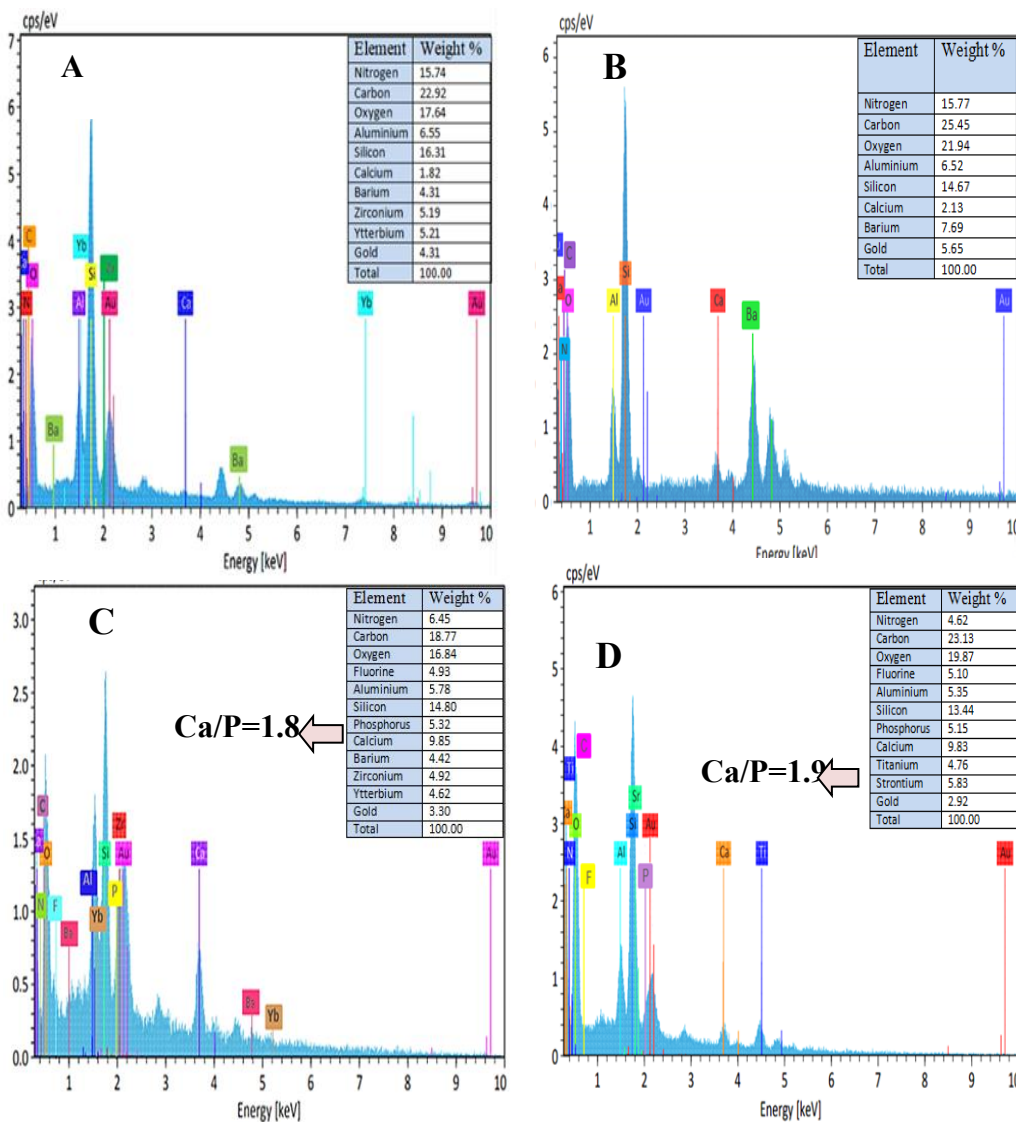
The mean values of calcium and phosphorus elements were used to calculate the calcium-to-phosphorus ratios. The mean values and standard deviation of Ca, P, and Ca/P ratio for the restorative materials after 28 days of storage in PBS are represented in Table (4).

**Table (4):** The mean and standard deviations of Ca, P and Ca/P ratio for restorative materials after storage in PBS that recorded by EDX analysis

Restorative material types	N	Ca element analysis	P element analysis	Ca/p ratio
A (Tetric powerFill)	8	1.87 ± 0.05	0	0
B (ever X Posterior)	8	2.29 ± 0.02	0	0
C (Cention N)	8	9.83 ± 0.02	5.31 ± 0.02	1.84 ± 0.005
D (Predicta bioactive)	8	9.81 ± 0.01	5.10 ± 0.01	1.91 ± 0.011

N: Eight cavities per four teeth in each group

The mean values and standard deviation of Ca, P, and Ca/P ratio for the tooth structure (i.e, gingival enamel margin) adjacent to the restoration after 28 days of storage in PBS are represented in Table (5).

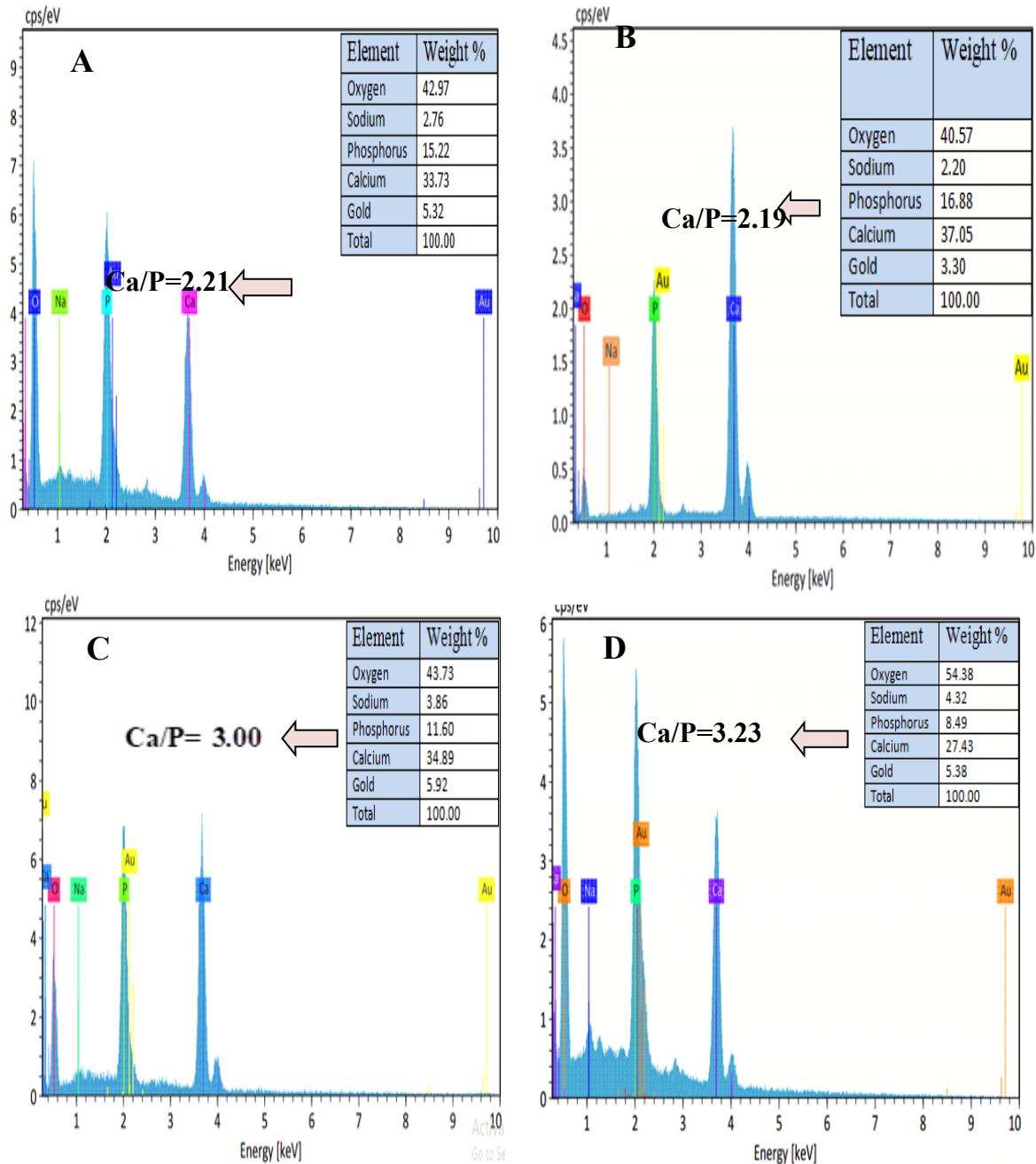


**Figure (5):** The EDX spectra after storage in PBS for 28 days of Tetric powerFill (A), ever X Posterior (B), which represented no phosphorus peak; Cention N (C), and Predicta bioactive (D) adjacent to tooth structure representing the phosphorus peak identification and the Ca/P ratio.

**Table (5):** The mean and standard deviations of Ca, P and Ca/P ratio for gingival enamel margins adjacent to the restorations after storage in PBS that recorded by EDX analysis.

Restorative material types	N	Ca element analysis	P element analysis	Ca/p ratio
A (Tetric powerFill)/Tooth	8	31.89 ± 1.67	14.37 ± 0.86	2.21 ± 0.03
B (ever X Posterior)/Tooth	8	36.05 ± 1.58	16.42 ± 0.56	2.19 ± 0.03
C (Cention N)/Tooth	8	34.78 ± 0.42	11.53 ± 0.40	3.01 ± 0.07
D (Predicta bioactive)/Tooth	8	28.18 ± 1.78	8.80 ± 0.61	3.20 ± 0.03

N: Eight cavities per four teeth in each group



**Figure (6):** The EDX spectra of tooth structure (gingival enamel) adjacent to Tetric powerFill (A); ever X Posterior (B); Cention N (C); Predicta bioactive (D) after storage for 28 days in representing the Ca/P ratio.

## DISCUSSION

Marginal adaptation and microleakage are considered important properties to determine the longevity of restorative materials of a posterior composite (44). It is tough, particularly in the class II gingival margin, to attain a uniformly sealed interface, which is necessary to increase restoration durability (9,10). The selection of the gingival margin of the class II box cavity as an area of investigation is based on the fact that previous studies stated that most defects that occur in the margin of restoration were located gingivally rather than the mesio-occlusal and the disto-occlusal margins (45,46).

Actually, the success in restoring a class II cavity lesion among the posterior teeth depends on the types of restorative materials (47,6). From this point, and according to the results obtained in this study, the restorative material types can affect their marginal adaptation. The Tetric powerFill showed the lowest gap width mean ( $6.50 \pm 1.61$ ). This could be explained by the addition of co-polymers (pre-polymerized fillers) to the fillers content, which known as a special stress reliever that acts as a “microscopic spring”, allowing reliable offsetting and dropping in the stress created during the polymerization process, let down the modulus of elasticity to about (10Gp) while for standard glass filler is about (71Gp) (48,49). On the other hand, the incorporation of Beta-allyl sulfone, which is a chain transfer addition fragmentation agent (AFCT), in the growing network leads to modulation of the radical chain-reaction that is essentially unregulated so that it behaves more like a “step-growth polymerization” and produces a more homogenized network structure (4,50).

The current study agrees with Par *et al.* (2021), who investigated the marginal integrity of four bulk-fill composites (Tetric powerFill, Filtek one, Tetric power Flow, and X-tra base) utilizing the SEM and found that the Tetric powerFill composite showed the highest continuous margin percentage with enamel margin (51). In the present study, the ever X Posterior show the highest gaps width mean ( $13.05 \pm 3.68$ ) among all the tested groups this may explained by the fact that the visco-elastic properties of the material are highly affected the amount of contraction stress and

according to Papadogiannis *et al.* 2015 who find that the fibers addition to composite material leads to a rise of its modulus result in highest viscosity. Hence, this may interfere with material adaptation to the cavity (52). The current study agrees with Fronza *et al.* (26), found that high gap percentage and high polymerization stress were formed by ever X Posterior when compared to other bulkfill composites (Tetric Evoceram, SDR, and Filtek Bulk-Fill), thus may be due to its high inorganic content and resultant high elastic modulus (26).

The gap width mean for the Cention N was ( $7.50 \pm 1.09$ ), which is higher than Tetric powerFill ( $6.50 \pm 1.61$ ) but lower than Predicta bioactive ( $7.86 \pm 1.22$ ). The reason behind that is that the high molecular weight monomer "AUDMA" was added to Cention N to diminish polymerization shrinkage. Since "AUDMA" has just two methacrylate groups and the long-chain molecule has limited mobility, it is difficult to bring the methacrylate groups into close physical contact. Moreover, Cention N contains the hydrophilic "PEG-400DMA" in the liquid portion that may contribute to increased flowability, thus resulting in stronger bonds (53-55).

Samanta *et al.* (56), stated that there is less microleakage in Cention N when compared with flowable composite resin and GIC. This is explained by the fact that Cention N contains "Isofillers" which act as a (micro-spring) that provides a cushion which restricts the polymerization shrinkage (56). Regarding the Predicta bioactive, the gap width mean ( $7.86 \pm 1.22$ ) was higher than Tetric powerFill and Cention N but lower than ever X Posterior. This may be explained by the low viscosity of Predicta bioactive composite (as the Predicta type used in the current study is a low viscosity type, as claimed by the manufacturer). Yet, the filler content is expected to be low, and this polymerization shrinkage and its associated stress may compromise its adaptation and sealing of the margins (57). Thus, this result comes in agreement with Han *et al.*(58), who stated that when comparing the high-viscosity bulk-fill and sonic-activated composites to low-viscosity bulkfill composites, it was shown that the latter had larger gap creation measures (58).

Bioactivity in *vitro* is defined as "the ability of bioactive material to form a hydroxyl apatite (HA) particle or apatite-like layer on its surface when it comes in contact with phosphate-containing fluids for 28 days. Thus, storing the specimens for 28 days was accomplished in this study(59). In this study, the PBS was used as a physiological-like storage solution instead of simulated body fluid since it is free from  $\text{Ca}^{++}$  ion so the calculated calcium by EDX was only from the tooth and restoration. The PBS consists of the following composition in (Mm): KCl (2.7), NaCl (137),  $\text{Na}_2\text{HPO}_4$  (10),  $\text{KH}_2\text{PO}_4$  (1.8)(36). In the current study, the same sample was used for both FESEM and EDX analysis, in which the FESEM was utilized to determine the gap width along the interface, while the EDX was used to determine the compositional element for two regions of interest: the restoration border near the gap and the gingival enamel margin near the gap (60).

Both FESEM/EDX analyses were utilized as a technique to detect apatite formation on the surface of bioactive materials (61,62). The EDX results showed the presence of carbon, oxygen, silicon, and aluminium, which form the main components of the resin matrix in all samples' surfaces, together with gold as coating material (35). In the present study, the EDX spectra of Tetric powerFill and ever X Posterior show no phosphorus peak with Ca/P ratio of zero for both, while the EDX results for both Cention N and Predicta bioactive after storage in PBS indicated the P peak. In addition, the Ca/P ratio mean values for the Cention N and Predicta bioactive were  $(1.84\pm 0.005)$  and  $(1.91\pm 0.011)$ , respectively.

These results agree with Shafqat *et al.* (63), who stated in their investigation about the bioactivity of novel composite that the Ca/p ratio was about (1.9-2.0) (63). Moreover, Fahmy *et al.* (2021) in their research about the bioactivity of active bioactive composite found that the Ca/p ratio was about 1.7, and compared this result with the natural the Ca/p ratio in HA, which is about 1.67 (1.5-1.7)(37,64).

The EDX results in this study confirmed the FESEM image for the Cention N and Predicta bioactive represented the formation of apatite precipitate at the tooth-restoration interfacial surfaces between them.

Indeed, Cention N contains alkaline fluorosilicate glass under the name "Alkasite fillers" with a weight percentage of around (24.6%) which is responsible for ion release that plays a role in hydroxyapatite formation and deposition on the tooth surface and adjacent to a restoration (65). The Cention N is a hand mixing restorative material that, during mixing of the powder and liquid, there is an incorporation of voids and porosities, thus preventing polymerization in this area and increasing unpolymerized material that results in water sorption and dissolution of the materials, and due to the presence of alkaline fillers, there is more ion release (66,67).

Tiskaya *et al.* (68) found that the storage of Cention N in phosphate-containing solution for 14 days results in "apatite-like" phase precipitation (68). This result is in accordance with the current study and can explain the Cention N ability to seal a part of the gaps at the restoration-tooth interface, although the reduction in marginal leakage was statistically not significant.

One of the components of Predicta bioactive is Titanium dioxide, as provided by the manufacturer and confirmed with the EDX results. Indeed, the formation of HA is a chemical process that requires numerous specific circumstances. Firstly, it should be noted that the surface of  $\text{TiO}_2$  carries a negative charge, particularly under high pH conditions. This negative charge leads to the attraction of calcium ions to the surface. In turn, this attraction results in the formation of an oversaturated solution in proximity to the surface, ultimately leading to the formation of HA (69).

Furthermore, HA exhibits the highest level of stability within the calcium phosphate system when subjected to a pH range of 4.2 to 12. On the other hand, Predicta bioactive contains "HEMA," which is a hydrophilic monomer with increased solubility, which may explain its ability to release more ions and enhance its bioactivity. Actually, the major constituent of tooth hard tissues is the hydroxyapatite crystal, which contains calcium and phosphorus. Changes in the calcium/phosphate ratio are a sign that the hydroxyapatite's inorganic components have changed (70).

In this study, the gingival enamel margin adjacent to Cention N and Predicta bioactive groups recorded the Ca/P ratios mean values t were (3.01) and (3.20), respectively, which again indicated the HA precipitation.

## **CONCLUSIONS**

Within the limitations of the current study, it is possible to conclude that: It is possible to deduce that the marginal fitness can be influenced by various composite material types that were used. The Tetric powerFill composite represented the lowest gap width formation, while ever X Posterior represented the highest gap width formation. Bioactive restorative materials are considered promising restorations with potential clinical benefits

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## **Authors' Contribution**

Ibrahim HSh and Al-Askary RA completed conceptualization, formal analysis, funding acquisition, investigation, methodology, project administration, and resources, software. Supervision by Al-Askary RA. Validation, visualization, writing–original draft completed by Ibrahim HSh, Al-Askary RA. Writing–review editing by Al-Askary RA. All authors have read and approved the final manuscript.

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**Ethical statement:** An ethical approval was received from the “Research Ethics Committee” at the Faculty of Dentistry, Mosul University, Iraq, with clearance number (REC reference No. **UoM. Dent/H.DM.4/23**) before starting the investigation.

## **Conflict of interest**

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

**Availability of data and materials:** All data generated or analyzed during this study are included in this published article and its supplementary information files.

## **Declaration of Generative AI and AI-assisted technologies**

During the preparation of this work, the authors did not use AI tools. The authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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### قدرة تكوين الأبتايت والتكيف اللثوي لمادة ترميم مركبين حيويين (دراسة مقارنة في المختبر) هدير شاهبور ابراهيم<sup>1</sup>, رغد عدنان العسكري<sup>2</sup>

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#### الملخص

**الأهداف:** تهدف الدراسة الحالية إلى تقييم تأثير أنواع مختلفة من المواد الترميمية الحشوية الراتنجية ذات التعبئة بالكتلة الواحدة وتأثير تخزينها في محلول الفوسفات الملحي (PBS) على التكيف الهامشي عند هامش المادة التصالحية - مينا اللثة لترميم تجويف الدرجة الثانية. **المواد وطرق العمل:** تم اختيار ستة عشر ضرساً للعلل بشرياً خالياً من التسوس مع أحجام إطباقية مقارنة العرض الانسي- الوحشي. تم غرس كل سن في قالب من الراتنج الأكرليكي بمساعدة مساح الأسنان. وبعد ذلك تم تحضير تجاويف مستقلة عن بعضها صندوقية الشكل من الدرجة الثانية (جهة الإطباق الانسي وجهة الإطباق الوحشي) في كل سن بمساعدة إطار معدني مسبق الصنع. تم تقسيم عينات الأسنان عشوائياً إلى أربع مجموعات (العدد = 4) سناً لكل مجموعة، اعتماداً على أنواع المواد الترميمية (المجموعة أ: تم ترميمها باستخدام مادة Tetric powerFill؛ المجموعة ب: تم ترميمها باستخدام مادة ever X Posterior؛ المجموعة ج: تم ترميمها باستخدام مادة Cention N؛ والمجموعة د: تم ترميمها باستخدام مادة Predicta النشطة بيولوجياً). تم حشو الأسنان لكل مادة وفقاً لتعليمات المصنع وبمساعدة قالب مصنوع من السيليكون. بعد ذلك، خضعت جميع عينات الأسنان للتدوير الحراري لمدة 1000 دورة في حمامات الماء المقطر (5 درجة مئوية -55 درجة مئوية) ( $1 \pm$  درجة مئوية) مع زمن سكون قدره 30 ثانية ووقت نقل 10 ثوانٍ لكل حمام. ثم تم خزن عينات الأسنان في محلول الفوسفات الملحي (PBS). تم إخضاع عينات الأسنان التي سيتم إرسالها إلى تحليلات المجهر الإلكتروني الماسح للانبعاثات الميدانية/مطيافية تشتت الطاقة بالأشعة السينية أولاً إلى التقسيم الطولي في الاتجاه الشدغي- اللساني ثم أفقياً لفصل قطع الأسنان عن قالب الأكرليكي، ثم تم تنظيف العينات باستخدام الموجات فوق الصوتية وإرسالها للتحليل. بعد ذلك تم تحليل نتائج المجهر الإلكتروني الماسح للانبعاثات الميدانية/مطيافية تشتت الطاقة بالأشعة السينية باستخدام اختبار انوفوا ذو الاتجاه الواحد واختبار النطاق المتعدد لندكن. ثم تم تحليل البيانات المجمعة لتقييمها ومقارنتها بمستوى معنوي 5%.

**النتائج:** كان هناك اختلاف كبير في التكيف الهامشي بين أنواع المواد الترميمية الراتنجية. لقد أظهرت الألياف المقواة ever X Posterior أعلى عرض للفجوات الهامشية بالميكرومتر يليه Cention N ، بينما أظهرت Tetric powerFill أقل عرض للفجوات الهامشية بين المجموعات الأخرى. كشفت أطراف تشتت الطاقة بالأشعة السينية لكلا المادتين النشطتين بيولوجياً بعد التخزين عن ظهور قمة الفوسفور مع نسبة الكالسيوم إلى الفوسفور أعلى من نسبة الهيدروكسيأبتايت الطبيعية والتي تشير إلى النشاط الحيوي لهذه المواد بينما بالنسبة لكل من Tetric powerFill و ever X Posterior لم يكن هناك أي تغيير في التحليل التركيبي للعناصر. **الاستنتاجات:** يمكن أن يتأثر التكيف الهامشي عند السطح البيني بين المادة الترميمية الراتنجية وحواف مينا اللثة في ترميم تجويف الدرجة الثانية بنوع وتركيب وخصائص المواد الترميمية الراتنجية المستخدمة. أظهرت المواد الترميمية النشطة بيولوجياً بعد تخزينها تأثيرات إيجابية من حيث تقليل عرض الفجوات الهامشية والتسرب الدقيق.

**الكلمات المفتاحية:** بريدكتا بايوأكتيف الكتلتي، سينشن إن، هيدروكسي أبتايت، التكيف الحاقفي.