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A Descriptive Study of Alkasite, Bulk Fill, and Fiber-Reinforced Restoration Bioactivities

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Abstract

Aims: This in vitro investigation was used to evaluate and compare the bioactivity of several restorative materials (Cention® Forte, Tetric Power Fill bulk fill and evere X Posterior™). **Materials and methods:** Disc-shaped specimens of 10 mm in diameter and 2 mm in thickness were made for Cention® Forte, Tetric PowerFill bulk fill, and EvereX Posterior™ in order to evaluate their bioactivity. The manufacturer's instructions were followed while handling the materials. Dental floss was used to suspend the samples in plastic containers that filled up to 25 milliliters with phosphate-buffered saline (PBS) for 28 days, the pH was 7.4 at 37°C, and the solution was changed every three days. The samples underwent cleaning, drying, and analysis using Field Emission Scanning Electron Microscope (FESEM)/ Energy Dispersive X-ray (EDX). **Results:** Hydroxy apatite crystals precipitated as nano-spherical needle-like shapes on the surface of Cention® Forte. The Ca\P ratios of Tetric PowerFill bulk fill and evereX Posterior™ were (0.69) and (0.71), respectively, whereas Cention® Forte had a Ca\P ratio of 1.86, which was more than the normal Ca\P ratio of dentin which is 1.67. **Conclusions:** Over 28 days in phosphate-buffer saline, Cention® Forte exhibited the ability of HA precipitation on its surface with a Ca/P ratio comparable to that of natural HA.

دراسة وصفية لحيوية حشوة الالكاسايت والحشوة ذات التعبئة بالكتلة الواحدة والحشوة المدعمة بالالياف

الملخص

الأهداف: تهدف هذه الدراسة إلى تقييم ومقارنة النشاط الحيوي لبعض المواد الترميمية الخلفية (Cention® Forte وTetric PowerFill bulk fill وevereX Posterior™). **المواد وطرائق البحث:** تم تصنيع عينات على شكل اقراص يبلغ قطر كل قرص 10 مم وسمكه 2 مم لكل من (Cention® Forte، و Tetric PowerFill، evereX Posterior™) من أجل تقييم نشاطها الحيوي. تم التعامل مع المواد وفقا لتعليمات الشركة المصنعة. تم استخدام خيط تنظيف الأسنان لتعليق العينات في حاويات بلاستيكية مملوءة بما يصل إلى 25 ملليلترًا بمحلول ملحي بالفوسفات (PBS) لمدة 28 يومًا، وكان الرقم الهيدروجيني 7.4 عند 37 درجة مئوية، وتم تغيير المحلول كل ثلاثة أيام. خضعت العينات للتنظيف والتجفيف والتحليل باستخدام المجهر الإلكتروني لمسح الانبعاثات الميدانية (FESEM)/ الأشعة السينية المشتتة للطاقة (EDX). **النتائج:** ترسبت بلورات هيدروكسي الأباتيت باشكال نانوية كروية تشبه الإبرة على سطح Cention® Forte. كانت نسب Ca\P ل Tetric PowerFill و evereX Posterior™ (0.69) و(0.71)، على التوالي، في حين أن نسبة Ca\P في Cention® Forte تبلغ 1.86، وهي أكثر من نسبة Ca\P الطبيعية للعاج وهو 1.67. **الاستنتاجات**: على مدار 28 يومًا من الغمر في محلول ملحي بالفوسفات، أظهر Cention® Forte قدرة على ترسيب هيدروكسي الاباتيت على سطحه مع نسبة Ca/P مماثلة لتلك الموجودة في HA الطبيعي.

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INTRODUCTION

The calcium phosphate mineral (carbonated hydroxyapatite) is found in dental hard tissues such as dentin, enamel, and cementum. Collagen fibrils are also known to strengthen the interfaces between these tissues. Dental material scientists have been trying to biomineralize dentin beneath restorations to reinforce intact dentin biomimetically. Though they vary in their levels of bioactivity, all materials utilized in dental restoration are biomaterial [(1)].

In the context of restorative dentistry, the ability of a substance to release ions, remineralize, and generate hydroxyapatite crystals on its surface when comes in contact with physiological body fluid is referred to as being bioactive [(2,3)].

Bioactive material helps in remineralizing and reinforcing hard dental tissue, so helps in improving the mechanical properties. Chemical bonding to hard dental tissues aids in the reduction of sensitivity. Because of the elevated pH level supplied by mineral saturation, tooth structure is protected from the detrimental effects of all forms of acids and decreases the formation of matrix metalloproteinase, so it helps in eliminating collagen destruction. The release of calcium and phosphorus ions from their composition results in the formation of a mineral similar to natural hydroxyapatite. Tissue formation by stimulating migration, proliferation, and differentiation of odontogenic cells in the presence of growth factors [(4-6)].

A rise in the Ca/P ratio is a crucial indicator of remineralization because it makes it possible to assess whether a material is suitable for use on demineralized tooth tissue. An appetite structure is considered a calcium-deficient non-stoichiometric crystal if its Ca\P ratio is less than 1.67. In natural teeth, the typical Ca/P ratio is 1.67 [(7,8)].

There aren't many scientific studies on Cention® Forte or everX Posterior™, particularly regarding bioactivity. This in vitro investigation aimed to assess and compare the bioactivity of several posterior restorative materials, including evereX Posterior™, Tetric Powerfill bulk fill, and Centon® Forte. Null hypothesis there is no significant difference in bioactivity among Cention® Forte, Tetric PowerFill bulk fill, and everX Posterior™ restorations, while the alternative is the opposite.

MATERIAL AND METHODS

The materials used in this study and their composition are listed in Table (1).

Study Design

Each of the three main groups Cention® Forte, Tetric PowerFill, and everX Posterior™ contains 4 specimens, one specimen will not be immersed in phosphate buffer saline considering it a control specimen, while the remaining 3 specimens will be immersed in the phosphate buffer saline.

Table (1): Materials and Composition

Materials	Composition	Manufacturer and batch number
Cention® Forte	Ca-Fl-Si glass, Ba-Al-Si glass, Ca-Ba-Al-Fl-Si glass, Ytterbium trifluoride, UDMA, DCP, PEG-400-DMA	IvoclarVivadent, Liechtenstein Z01DTR
Tetric Power Fill bulk fill	Barium glass, Ytterbium trifluoride, mixed oxide (SiO2/ZrO2), Copolymers Initiators, Stabilizer Pigment, Additives,Bis-GMA,UDMA, Bis-EMA, Bis-PMA, DCP, D3MA	Ivoclar Vivadent, Liechtenstein Z02SZY
Everex Posterior™	Short E-glass fiber Silicon dioxide, Barium glass, Photo initiator, BisGMA, PMMA, TEGDMA	GC, Tokyo, Japan 2107051
PBS	136.4 mM NaCl, 2.7 mM KCl 8.2 mM Na2HPo4 1.25 mM KH2Po4	Sigma, USA SLCF6814

Method

The disc shape specimens were made with these measurements (diameter: 10 mm, thickness: 2 mm) according to ISO 23317-2014 (Implants for surgery- In vitro evaluation for apatite-forming ability of implant materials).

Every type of restoration was created using a custom-designed plastic mold, and the samples were assembled following the manufacturer's instructions. To guarantee the smoothness and levelness of the sample, it was covered with two Mylar strips and two glass microscope plates. A load of 500 g was applied over the glass for 30 seconds to allow excess material to leak out. The load was then removed, and the material was cured in accordance with the manufacturer's instructions. The strips, glass plates, excess material, and mold were removed [(9)]**.** The samples were polished underwater using abrasive sandpaper (600 and 800grit) [(10)]**.**

A hole was made in the middle of the sample to make it suspended inside the container through dental floss, the hole was made by using a round bur with a high-speed air motor, and each specimen was immersed in 25 mL of phosphate-buffered saline in a plastic container, the solution pH: 7.4, at 37°C for 28 days these parameters were used to simulate body fluid condition that allow for hydroxy apatite precipitation**.** The phosphate buffer saline was prepared by mixing 9.8 gm of powder in 1 Liter of deionized water according to manufacture directions[(11-13)]**.** Every three days, the PBS changed for refreshing [(4)]**.**

After 28 days, the samples were removed from the solution, cleaned with deionized water, and dried. A field emission scanning electron microscope (FESEM) was used to examine the microstructure and morphology of the samples both before and after they were submerged in the solution. Energy dispersive X-ray (EDX) analysis of the chemical composition was conducted to determine the weight percentage of the sample surface [(14)].

RESULTS

The characteristics of the Cention® Forte sample before and after immersion in

PBS was different. The FESEM displayed precipitations of Nano spherical needle-like shape. The EDX analysis revealed a decrease in F (5.40 to 2.90) and an increase in the weight percentage of Al (6.51 to 7.40), Si (13.01 to 15.35), Ca (2.53 to 5.38), and P (0.78 to 2.88). After immersion, the Ca / P ratio was 1.86. The FESEM and EDX of Cention ® Forte are displayed in Figure (1) both before and after a 28-day immersion in PBS.

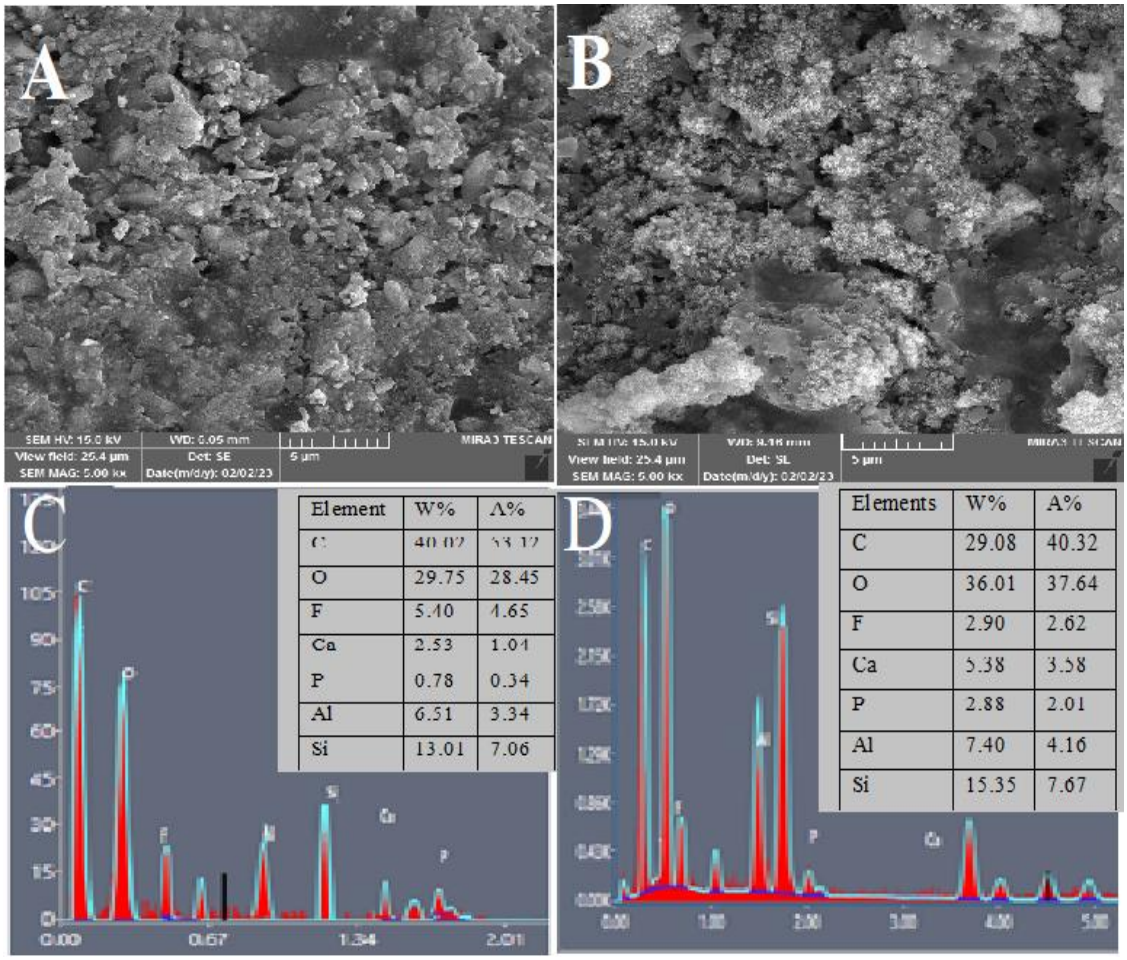

Figure (1): Cention® Forte FESEM(A) before immersion in PBS. (B) after immersion in PBS. (C) EDX before immersion in PBS. (D)EDX after immersion in PBS.

Before immersion in PBS, the everX Posterior™'s surfaces were smooth, according to FESEM imaging. However, during 28 days of immersion, a tiny number of spheroid body were seen. The elements' composition varied according to the EDX analysis: Al elevated (6.11 to 7.02), Si (17.09 to 18.1), P (3.11 to 5.05), Ca (2.27 to 3.62), B was 0.27 before it vanished after immersion, and F once again dropped from 1.61 to 0.47. Following immersion in PBS. The Ca\P ratio was 0.71. The FESEM and EDX of everX Posterior ™ are displayed in Figure (2) both before and after a 28-day immersion in PBS.

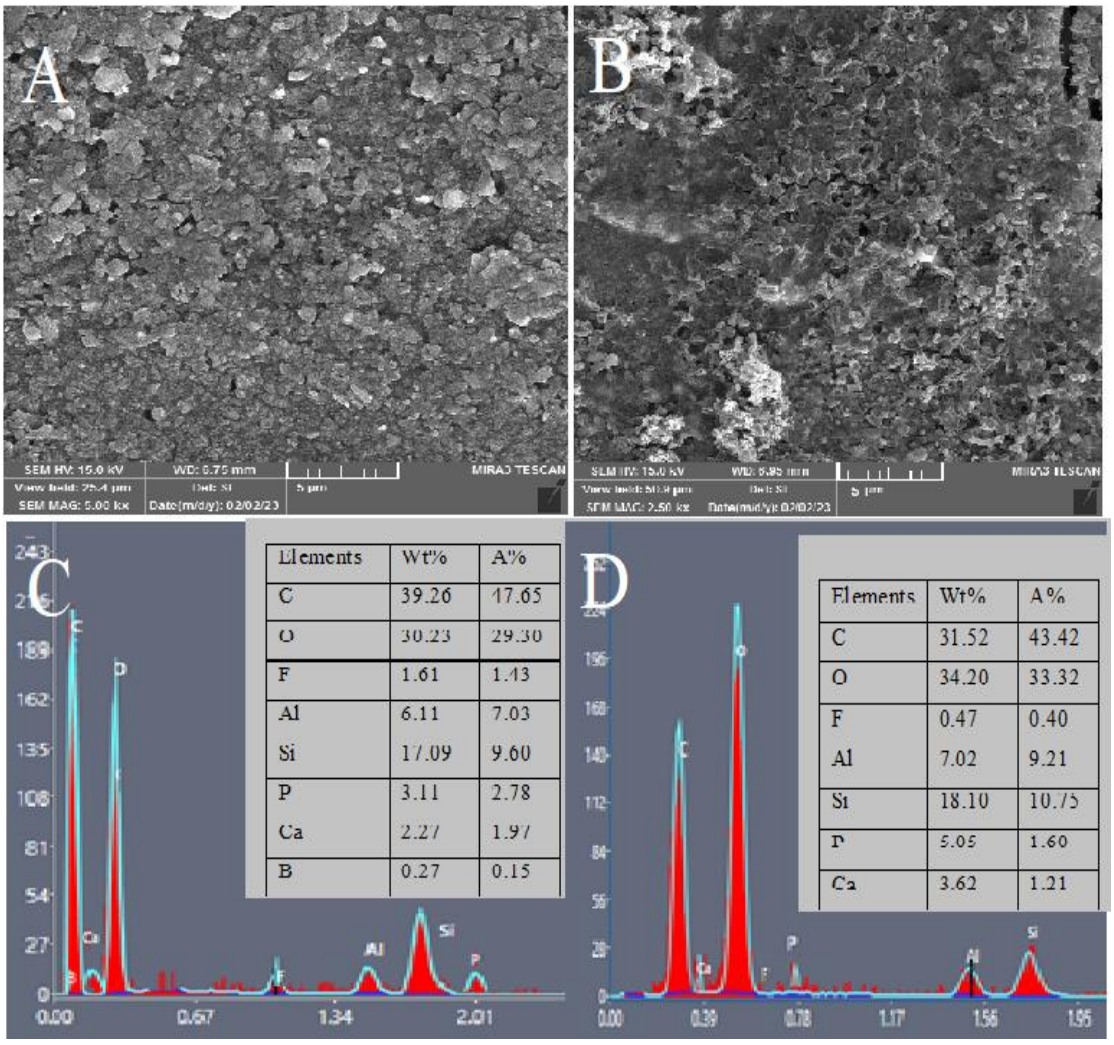

Figure (2): EverX Posterior™ FESEM(A) before immersion in PBS. (B) after immersion in PBS. (C) EDX before immersion in PBS. (D)EDX after immersion in PBS.

Prior to immersion, Tetric PowerFill's surface, as shown by FESEM analysis, was smooth, but after immersion in PBS, there were some precipitations of spheroid entities of varying sizes. Tetric PowerFill's EDX revealed elevations in Si (12.79 to 18.02), P (2.11 to 5.21), Ca (1.48 to 3.60), Al (3.35 to 3.57), and F (1.67 to 1.39). Following immersion in PBS, we noticed that the Ca/P ratio was 0.69. Tetric PowerFill's FESEM and EDX analyses both before and after immersion in PBS are shown in Figure (3).

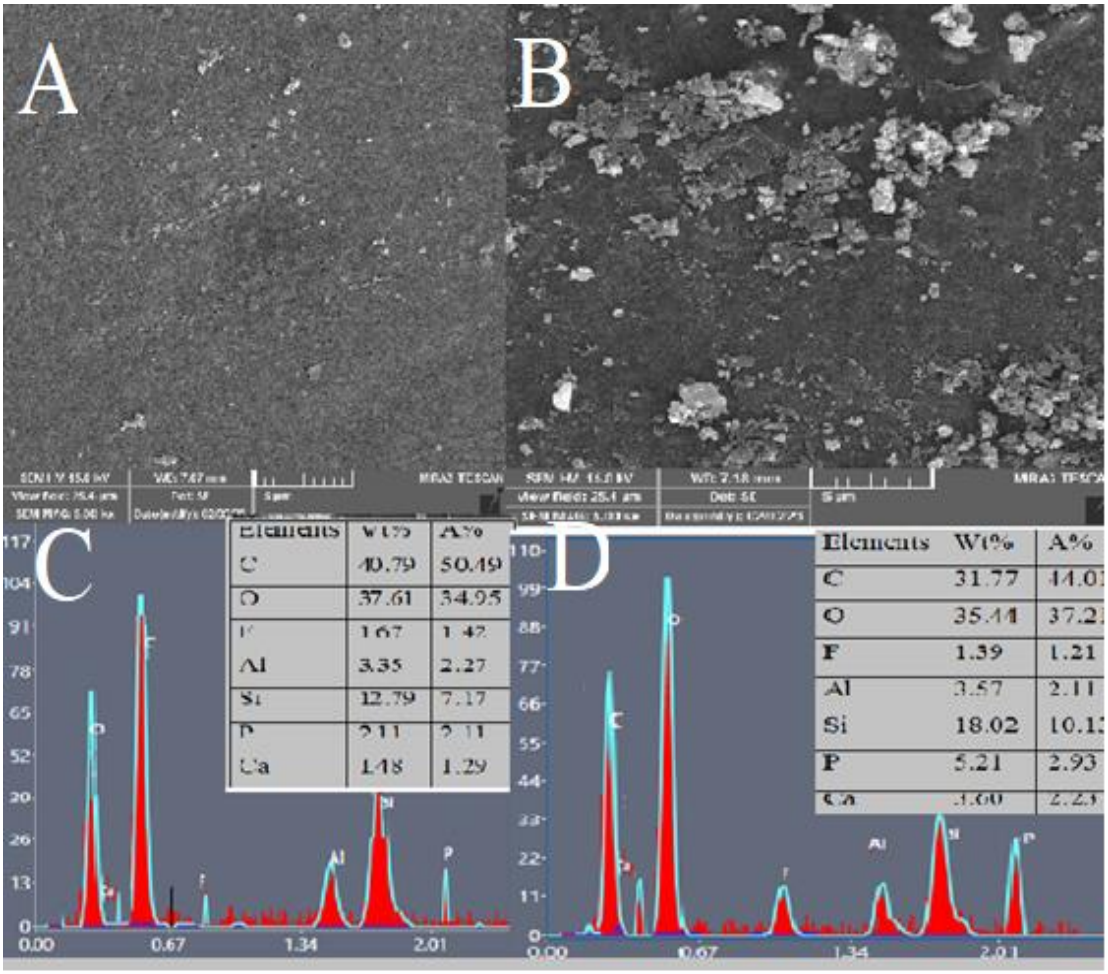

Figure (3): Tetric PowerFill FESEM (A) before immersion in PBS. (B) after immersion in PBS. (C) EDX before immersion in PBS. (D)EDX after immersion in PBS.

Prior to immersion, Tetric PowerFill's surface, as shown by FESEM analysis, was smooth, but after immersion in PBS, there were some precipitations of spheroid entities of varying sizes. Tetric PowerFill's EDX revealed elevations in Si (12.79 to 18.02), P (2.11 to 5.21), Ca (1.48 to 3.60), Al (3.35 to 3.57), and F (1.67 to 1.39). Following immersion in PBS, we noticed that the Ca/P ratio was 0.69. Tetric PowerFill's FESEM and EDX analyses both before and after immersion in PBS are shown in Figure (3).

DISCUSSION

Bioactivity is the ability of the material to release ions and enhance the remineralization when comes in contact with physiological body fluid. The restoration's solubility, the concentration of ions, the temperature, the duration, and the environment's pH all affect how many ions are released. When the pH drops and specimens are kept in solution at high temperatures for lengthy periods of time, ion release rises. [10, 15-17].

Phosphate buffer saline (PBS) is a physiologic solution that is frequently employed in biochemistry to simulate human extracellular fluid. The utilization of PBS to ascertain the capability of materials to release the Ca^{+} from itself [18].

The hydrolysis and dissolution of calcium silicate led to the exchange of ions, which initiated the creation of hydrated silica gel, the precursor to the apatite crystal [19]. As sodium and calcium moved and were released into the solution, hydrogen reacted with silica, the SiO^{-} negative group reacted with the positive charge Ca^{+}, and PO_4^{-} sorption took place, resulting in hydroxyapatite. Before crystallizing as carbonated hydroxyapatite, it first appears as an amorphous layer with a Ca/P ratio of 1.67 or higher [20]. The carbonate group indicates that carbonated hydroxyapatite is present [21].

According to the result that we obtained the null hypothesis was rejected and the alternative hypothesis was accepted where there were significant differences in bioactivity among the restoration that was used.

Cention® Forte with alkaline fillers can be used in self-cure or light-cure polymerization modes, and it can be applied in a single layer (bulk fill). Self-etching and adhesive, it can be used as an alternative to amalgam, self-adhesive restoration materials are recommended since not time-consuming and technically not sensitive as bonding operation is needed [22,23].

After immersion, the Ca\P ratio for Cention® Forte was 1.86, greater than the typical molar ratio of 1.67 because of the high concentration of Ca (5.38 wt%) compared to P (2.88 wt%). Over the samples, an amorphous calcium phosphate layer builds up. The solution containing supersaturated carbonate ions leads to precipitation and further mineralization [21]. In addition, UDMA, which is more soluble than TEGDMA, is included in Cention® Forte. The release of unreacted molecules is largely dependent on the degree of conversion. The order in which different monomer systems change to higher degrees of conversion is Bis-GMA < Bis-EMA < UDMA < TEGDMA. As conversion rises, the number of unreacted monomers decreases, which lowers the solubility [24].

According to EDX analysis, the Tetric PowerFill bulk fill's Ca\P ratio was 0.69, indicating that the precipitate that was produced was weakly crystallized apatite low in calcium since there is not as much Ca (3.60 wt%) as there is P (5.21 wt%). The use of bonding systems limits the bioactivity of resin composites toward the tissues underneath the filling, in addition to the fact that most resin composites are not meant to release significant amounts of calcium, phosphorus, and fluoride [1,10,25,26]. Moreover, Tetric PowerFill's low solubility is caused by step-growth polymerization employed by β- allyl sulfone, which produces a more stable polymerization in which there are no unreacted monomers left over [27].

The evereX's Posterior™ is a restoration in which its fibers are randomly arranged to show an isotropic reinforcing effect in a variety of orientations rather than only a few specific ones [28,29]**.** The resin matrix contains Bis-GMA, TEGDMA, and PMMA, forming a matrix called a semi Interpenetrating Polymer Network (semi-IPN), inorganic fillers barium glass with electrical (E)-glass fibers [30,31]**.**

The Ca\p ratio of the evereX Posterior™ was 0.71, a lower value than the typical ratio of 1.67. There are several explanations for this, one of which is that glass E, is a calcium-aluminum-borosilicate glass. This fiber is concerning because it includes boron oxide, which is very resistant to water attack and has a low alkali content. The concentration of Ca (3.62 wt%) in the sample was lower than that of P (5.05 wt%). Moreover, the monomer of everX Posterior™ is composed of TEGDMA, which is less soluble than PMMA and BisGMA. Small amounts of fluoride are present in the everX Posterior™; as demonstrated by the EDX, the fluoride content before immersion was 1.61 and decreased to 0.47 [32-35]**.**

CONCLUSION

Over 28 days in phosphate-buffer saline, Cention® Forte exhibited the ability of HA precipitation on its surface with Ca/P ratio comparable to that of natural HA.

Ethical statement

This study was approved by the Research Scientific Committee board at the University of Mosul, College of Dentistry in Iraq with a reference number (UoM.Dent/H.DM.1/23) on 9/1/2023.

Conflicts of Interest

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

REFERENCES

1. Vallittu PK, Boccaccini AR, Hupa L, Watts DC. Bioactive dental materials-Do they exist and what does bioactivity mean? Dent Mater J. 2018; 34(5): 693-694**.**
2. Tiskaya M, Shahid S, Gillam D, Hil R. The use of bioactive glass (BAG) in dental composites: A critical review. Dent Mater J.2021; 37 :296–310.
3. Spagnuolo G. Bioactive dental materials: the current status. Materials. 2022; 15(6): 2016.
4. Hamdy TM. Bioactivity: a new buzz in dental materials. EC Dent Sci. 2018;17(8): 1-6.
5. Braga RR, Fronza BM. The use of bioactive particles and biomimetic analogues for increasing the longevity of resin-dentin interfaces: A literature review. Dent Mater J.2020; 239(1): 62-68.
6. Nunez C, Altamirano Gaete D, Maureira M, Martin J, Covarrubias C. Nanoparticles of bioactive glass enhance biodentine bioactivity on dental pulp stem cells. Materials. 2021; 14: 2684.

7. Khan AS, Syed MR. A review of bioceramics - based dental restorative materials. Dent Mater J. 2018; 38(2): 163-176.
8. Ghilotti J, Fernández I, Sanz JL, Melo M, Llena C. Remineralization Potential of Three Restorative Glass Ionomer Cements: An In Vitro Study. J Clin Med. 2023;12(6): 2434.
9. Bahari M, Chaharom MEE, Daneshpooy M, Gholizadeh S, Pashayi H. Effect of bleaching protocols on surface roughness and biofilm formation on silorane-based composite resin. Dent Res J. 2019;16 (4): 264.
10. Kasraei S, Haghi S, Valizadeh S, Panahandeh N, Nejadkarimi S. Phosphate Ion release and alkalizing potential of three bioactive dental materials in comparison with composite resin. Int J Dent. 2021;2021: 8.
11. Odermatt R, Par M, Mohn D, Wiedemeier DB, Attin T, Taubock TT. Bioactivity and physico-chemical properties of dental composites functionalized with nano-vs. micro-sized bioactive glass. J Clin Med.2020; 9(3): 772.
12. Abdalla MM, Lung CYK, Neelakantan P, Matinlinna JP. A novel, doped calcium silicate bioceramic synthesized by sol–gel method: Investigation of setting time and biological properties. J Biomed Mater Res. 2020;108(1): 56-66.
13. Gudic S, Vrsalovic L, Kvrgic D, Nagode A. Electrochemical behaviour of Ti and Ti-6Al-4V alloy in phosphate buffered saline solution. Materials. 2021;14 (24): 7495.
14. Bellucci D, Salvatori R, Anesi A, Chiarini L, Cannillo V. SBF assays, direct and indirect cell culture tests to evaluate the biological performance of bio glasses and bioglass - based composites: Three paradigmatic cases. Mater Sci Eng.2019; 96: 757-764.
15. Han L, Okiji T. Bioactivity evaluation of three calcium silicate-based endodontic materials. Int Endod J. 2013; 46(9): 808-14.
16. Tarle Z, Par M. Bioactive dental composite materials. Med Sci .2018; 45: 83-99.
17. Marovic D, Par M, Posavec K, Marić I, Štajdohar D, Muradbegović A, Tauböck TT, Attin T, Tarle Z. Long-term assessment of contemporary ion-releasing restorative dental materials. Materials. 2022 Jun 7;15(12):4042.
18. Simila HO, Karpukhina N, Hill RG. Bioactivity and fluoride release of strontium and fluoride modified Biodentine. Dent Mater J. 2018 ;34(1): e1-7.
19. Sfeir G, Zogheib C, Patel S, Giraud T, Nagendrababu V, Bukiet F. Calcium Silicate-Based Root Canal Sealers: A Narrative Review and Clinical Perspectives. Materials. 2021;14(4): 3965.
20. Hoikkala NPJ, Wang X, Hupa L, Smått JH, Peltonen J, Vallittu PK. Dissolution and mineralization characterization of bioactive glass ceramic containing endodontic sealer Guttaflow Bioseal. Dent mater J.2018; 37(6): 988-994.

21. Skallevold HE, Rokaya D, Khurshid Z, Zafar MS. Bioactive glass applications in dentistry. Int J Mol Sci.2019; 20(23): 5960.
22. Sadeghyar A, Lettner S, Watts DC, Schedle A. Alternatives to amalgam: Is pretreatment necessary for effective bonding to dentin? Dental Materials. 2022;38(11):1703-9.
23. Burrer P, Par M, Fürer L, Stübi M, Marovic D, Tarle Z, Attin T, Tauböck TT. Effect of polymerization mode on shrinkage kinetics and degree of conversion of dual-curing bulk-fill resin composites. Clinical Oral Investigations. 2023; 4:1-2.
24. De Brito O, De Oliveira I, Monteiro G. Hydrolytic and biological degradation of bulk-fill and self-adhering resin composites. Oper Dent. 2019; 44(5): 223-33.
25. Schmalz G, Hickel R, Price RB, Platt JA. Bioactivity of Dental Restorative Materials: FDI Policy Statement. Int Dent J. 2022; 73 :27-21
26. Tagocka R, Jaworska M, Mochol M. Self-adhesive, bulk-fill bioactive materials as an alternative to silver amalgam in restorative dentistry. Pomeranian J Life Sci. 2022; 68(2): 40-48.
27. Klarić N, Macan M, Par M, Tarle Z, Marović D. Effect of Rapid Polymerization on Water Sorption and Solubility of Bulk-fill Composites. Acta Stomatologica Croatica. 2022; 56(3):235.
28. Bijelic-Donova J, Garoushi S, Vallittu PK, Lassila LV. Mechanical properties, fracture resistance, and fatigue limits of short fiber reinforced dental composite resin. The Journal of prosthetic dentistry. 2016;115(1):95-102.
29. Mangoush E, Garoushi S, Lassila L, Vallittu PK, Säilynoja E. Effect of fiber reinforcement type on the performance of large posterior restorations: A review of in vitro studies. Polymers. 2021;13(21):3682.
30. Garoushi S, Gargoum A, Vallittu PK, Lassila L. Short fiber-reinforced composite restorations: a review of the current literature. Journal of investigative and clinical dentistry. 2018;9(3): e12330.
31. Rajaraman G, Eagappan AS, Bhavani S, Vijayaraghavan R, Harishma S, Jeyapreetha P. Comparative evaluation of fracture resistance of fiber-reinforced composite and alkasite restoration in class I cavity. Contemporary Clinical Dentistry. 2022 ;13(1):56.
32. Khan AS, Azam MT, Khan M, Mian SA, Rehman IU. An update on glass fiber dental restorative composites: a systematic review. Mater Sci Eng C. 2015;47: 26-39.
33. Toh W, Yap A, Lim S. In vitro biocompatibility of contemporary bulk-fill composites. Oper Dent. 2015; 40(6): 644-652.
34. Safwat EM, Khater AG, Abd-Elsatar AG, Khater GA. Glass fiber-reinforced composites in dentistry. Bulle Nati Res Cent. 2021; 45: 1-9.
35. Saleem M, Zahid S, Ghafoor S, Khalid H, Iqbal H, Zeeshan R, Ahmad S, Asif A, Khan AS. Physical, mechanical, and in vitro biological analysis of bioactive fibers-based dental composite. J Appl Polym Sci. 2021; 138(18): 50336. KMJ.