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Radiopacity and Microleakage Evaluation of Different Intermediate Materials

Farklı Kaide Materyallerinin Radyopasite ve Mikrosızıntıya Etkisinin Değerlendirilmesi

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ABSTRACT

Objective: The aim of this study is to compare the radiopacities of different types of materials with indications for application as a base under restorations and the microleakage of the final restorations with these materials applied as bases.
Methods: Standart Class I cavities were prepared in 90 caries-free molar teeth. The cavities were randomly divided into 9 groups according to the type of intermediate material to be applied (n=10): 1. High flowable composite, 2. Low flowable composite, 3. Fiber reinforced composite, 4. Giomer, 5. Ormocer, 6. Alkasite, 7. Bioactive composite, 8. High viscosity glass ionomer, 9. Glass carbomer. The base materials in each group were applied to the cavity floor and restoration was completed using a nanohybrid composite resin and an universal adhesive system. To evaluate radiopacity, radiographic images were taken using direct digital system and mean gray values were measured with ImageJ software. To analyse microleakage, specimens were subjected to thermocycling, immersed in 2% methylene blue solution for 24 hours, sectioned buccolingually and leakage values observed on the half-piece surfaces were examined under a stereomicroscope and recorded. Data were analysed using One-way Analysis of Variance, Tukey HSD Test and Pearson Chi-Square with Bonferroni-corrected Z Test (*P*<.05).
Results: In terms of radiopacity, while alkasite and low flowable composite showed the highest radiopacity, glass carbomer gave the lowest (*P*<.001). In terms of microleakage, High flowable composite, low flowable composite, ormocer, giomer and fiber reinforced composite showed similar (*P*<.001) and lowest microleakage values, while glass carbomer exhibited the highest microleakage value (*P*<.001).
Conclusions: Within the results of the present study, high flowable composite, giomer, ormocer and fiber-reinforced composite can be recommended to be applied under composite resins, since they give successful results in terms of microleakage and present radiographically sufficient radiopacity.

Keywords: Microleakage, Radiopacity, Intermediate materials, Bases

ÖZ

Amaç: Bu çalışmanın amacı, farklı tipteki materyallerin radyoopasitelerini, restorasyonların altına kaide olarak uygulanma endikasyonları olan bu materyallerin kaide olarak uygulandığı son restorasyonların mikrosızıntısını karşılaştırmaktır.
Yöntem: 90 adet çürüksüz azı dişinde Standart Sınıf I kaviteler hazırlandı. Kaviteler uygulanacak ara malzeme cinsine göre rastgele 9 gruba ayrıldı (n=10): 1. Yüksek akıcı kompozit, 2. Düşük akıcı kompozit, 3. Fiber takviyeli kompozit, 4. Giomer, 5. Ormocer, 6. Alkasit, 7. Biyoaktif kompozit, 8. Yüksek viskoziteli cam iyonomer, 9. Cam karbomer. Her gruptaki kaide malzemeleri kavite tabanına uygulandı ve nanohibrit kompozit reçine ve evrensel adeziv sistem kullanılarak restorasyon tamamlandı. Radyopasiteyi değerlendirmek için direkt dijital sistem kullanılarak radyografik görüntüler alındı ve ImageJ yazılımıyla ortalama gri değerler ölçüldü. Mikrosızıntıyı analiz etmek için numuneler termosiklusa tabi tutuldu, 24 saat boyunca %2 metilen mavisi çözeltisine daldırıldı, bukkolingual olarak kesitler alındı ve yarım parça yüzeylerde gözlenen sızıntı değerleri stereomikroskopta incelenerek kaydedildi. Veriler Tek Yönlü Varyans Analizi, Tukey HSD Testi ve Bonferroni düzeltmeli Z Testi ile Pearson Ki-Kare kullanılarak analiz edildi (*P*<.05).

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Bulgular: Radyopasite açısından alkasit ve düşük akışkanlığa sahip kompozitler en yüksek radyopasiteyi gösterirken, cam karbomer en düşük radyopasiteyi gösterdi (*P*<.001). Mikrosızıntı açısından Yüksek akıcı kompozit, düşük akıcı kompozit, ormoser, giomer ve fiber takviyeli kompozit benzer (*P*<.001) ve en düşük mikrosızıntı değerlerini gösterirken, en yüksek mikrosızıntı değerini cam karbomer sergiledi (*P*<.001).
Sonuç: Bu çalışmanın sonuçları kapsamında, mikrosızıntı açısından başarılı sonuçlar vermesi ve radyografik olarak yeterli radyopasite sunması nedeniyle yüksek akışkanlığa sahip kompozit, giomer, ormoser ve fiberle güçlendirilmiş kompozitlerin kompozit rezinlerin altına uygulanması önerilebilir.

Anahtar Kelimeler: Mikrosızıntı, Radyoopasite, Ara materyaller, Kaideler

INTRODUCTION

In restorative dentistry, there are various types of materials, named intermediate restoratives, which are applied up to the dentin surface before the final restorative material is placed in wide and deep restorations in order to protect the pulp-dentin complex, remaining healthy tooth tissues and to increase the survival rate of the restoration by reducing the polymerization shrinkage stresses of composite resins.[1-3] It has been reported that less microleakage can be promoted and superior physical and mechanical properties can be obtained with this two-layer placement technique, where enamel and dentin are more appropriately imitated.[4,5]

Adequate radiopacity of intermediate restorative materials enables clinicians to evaluate restoration integrity in detail. Additionally, it is necessary to determine the restoration margins correctly in the diagnosis of secondary caries.[6] For sufficient opacity it has been reported that material with a radiopacity slightly higher than or equal to enamel is ideal.[7]

Some materials which are declared to be applicable as intermediate restoratives in the manufacturer's instructions are high and low viscosity flowable composite resins, fiber reinforced composite resin, giomer, ormocer, alkasite, bioactive composite, glass ionomers, glass carbomer. When the studies evaluating the radiopacity of these intermediate materials were examined, no study was found in which most of them were evaluated together. Only a few studies have compared the radiopacity of some of these materials.[8-11]

Similarly, when the studies examining the effect of intermediatives on the microleakage of the final restoration were evaluated, very few studies were found. In one of these studies, microleakage of two different glass ionomers was compared with MTA, Biodentin and ProRoot.[4] In another study, microleakage of different bulk-fill composites were compared with that of flowable composite and resin modified glass ionomer[12] In a different study; microleakage of a low-viscosity composite resin and a resin-modified glass ionomer was compared.[3]

Therefore, the aim of the study was to compare the radiopacities of different types of materials with indications for application as a base under restorations and the microleakage of the final restorations with these materials applied as bases. The null hypotheses were 1) there is no difference between radiopacity of different intermediary bases; and 2) there is no difference between microleakage of restorations that have been applied different intermediatives as base.

METHODS

Ethical aspects

This in vitro study was approved by the Pamukkale University Faculty of Medicine Human Ethics Committee (Denizli, Turkey) with reference number E-60116787-020-119901.

Specimen Preparation

Before starting the study, ninety human molar teeth extracted for periodontal or surgical reasons were collected. The teeth were examined and evaluated for any caries, fractures, cracks or previous restorations on the crown parts, and the problematic teeth were not included in the study. Then, the soft attachments on the teeth were removed with the help of a scaler and all surfaces were cleaned with pumice and polishing rubber. Until the study was performed, the teeth were kept in distilled water at room temperature for a period not exceeding 30 days.

Roots of selected teeth were embedded in epoxy resin and Black I cavities were prepared on the occlusal surfaces of the teeth. Cavity preparation was done using the diamond fissure bur 836 under water cooling with an aerator. The bur was changed after every 5 preparations. The dimensions of the cavity were 3 mm in the bucco-lingual direction and 5 mm in the mesio-distal direction, and the depth of the cavity was prepared as 4 mm. The dimensions of the preparations were checked with a periodontal probe (Michigan-O probe, Nordent, IL, USA).

The cavities were randomly divided into 9 groups according to the type of intermediate restorative material to be applied (n=10). The manufacturer, lot and chemical content information regarding these nine different bases are given in Table 1.

Table 1. The manufacturer, lot and chemical content information regarding nine different intermediatives.

Applied intermediate material type	Material Name/Manufacturer (Lot number)	Ingredients
High viscosity composite	Gaenial Universal Injectable/GC (190920B)	Dimethacrylate monomers, Barium glass, silica 69% by weight
Low viscosity composite	Clearfil Majesty Flow/Kuraray (210025)	Silanated barium glass fillers, silanated colloidal silica 62% by vol, triethylene glycoldimethacrylate (TEGDMA), hydrophobic aromatic dimethacrylate
Fiber reinforced composite	Ever X Flow/GC (1911011)	Bisphenol A ethoxylate dimethacrylate (Bis-MEPP,) TEGDMA and Urethane dimethacrylate monomers (UDMA) short E-glass fibrils, barium glass fillers 70% by weight
Giomer	Beautiful Flow Plus-F03/Shofu (121786)	Bis-GMA, TEGDMA, Fluoro-boro silicate glass 67.3% by weight, 47% by volume
Ormocer	Admira Fusion Xtra/Voco (121786)	Ormoser resin, 84% silicon dioxide filler
Alkasite	Cention N/Ivoclar Vivadent (W96066)	Barium aluminum silicate glass, ytterbium trifluoride, isophiles, Calcium barium aluminum fluorosilicate glass, UDMA, Tricyclodecane-dimethanol dimethacrylate, Tetramethyl-xyylene-diurethane dimethacrylate, Polyethylene glycol 400 dimethacrylate
Bioactive Composite	Activa Bioactive Restorative/ Pulpdent (190617)	Silanated bioactive glass and diurethane modified by adding calcium, silanated silica and sodium fluoride, hydrogenated polybutadiene and other methacrylate monomers, modified polyacrylic acid and water
High viscosity glass ionomer	Ionostar Plus/Voco (1607068)	Fluoro-alumino-silicate glass, polyacrylic acid, tartaric acid
Glass carbomer	GCP Fill/GCP Dental (71712907)	Fluoro-aluminosilicate glass, apatite, polyacidsgloss: modified polysiloxanes

The intermediate materials were placed the cavity floor with 2 mm height in accordance with the manufacturer's application recommendations. Except for the high viscosity glass ionomer and the glass carbomer groups, the adhesive application was performed before the base application. The universal adhesive (Clearfil S3 Bond Universal, Kuraray, Japan) was applied in selective etching mode. After the adhesive and base application, the restoration of the teeth was completed with a nanohybrid posterior composite resin (Clearfil Majesty Posterior, Kuraray, Japan) using the oblique layering technique.

The posterior composite resin was polimerized with a LED lamp at a distance of 1 mm (1000 mW/cm2, using standart power curing mode of VALO Cordless, Ultradent, South Jordan, Utah) for 20 seconds.

Radiopacity Evaluation

To assess radiopacity, samples were placed and fixed on number 2 phosphor plates (PSPIX® Imaging Plates, Sopro, France). Radiographs were obtained using a dental intraoral x-ray device (Gendex Expert DC, Hatfield, PA, USA) at 65 kV, 7 mA, 0.24 s duration, 30 cm focal-phosphorus plate distance. The central X-ray was directed perpendicular to the phosphor plate surface and the head of the X-ray device was kept in the same position throughout the study to ensure standardization. The phosphor plate was then scanned with a digital imaging system (ExpressTM; Instrumentarium Dental, Tuusula, Finland). The resulting radiographic images were saved in tagged image file format (TIFF) (Figure 1). These images were evaluated by a dentomaxillofacial radiologist (GA) with 5 years of clinical experience on a medical computer (Barco Medical, Kortrijk, Belgium).

For each sample; The mean gray values (MGVs) of enamel, dentin, intermediate material, and overlying composite resin were measured using ImageJ software (National Institutes of Health, Bethesda, MD, USA). Measurements were repeated from 10 different points and averaged. Gray values were determined for each point using the “Analyze/Measure” tool and calculated automatically by ImageJ software. The gray value of each pixel was displayed on a scale ranging from 0 (black) to 255 (white) (Figure 2).

Microleakage Evaluation

To determine the microleakage, the samples were thermocycledusing a thermal cycler device (10000 times, 5-55 °C, 30 seconds) (ModDental, Esetron Smart Robot Technologies, Ankara, Turkey). Afterwards, the samples were kept in 2% methylene blue solution for 24 hours, buccolingually divided into two equal parts, and the dye leakage formed on the restoration edges in each piece was examined by the other investigator who did not operate the restorations (GA) with a stereomicroscope (Olympus SZ60, Tokyo, Japan) at ×40 magnification and leakage on the cavity walls at the tooth-restoration interface was scored as follows:[13]

0: No leakage
1: Leakage not exceeding half of the cavity wall
2: there is leakage at the entire cavity wall
3: there is leakage at the cavity floor (Figure 3).

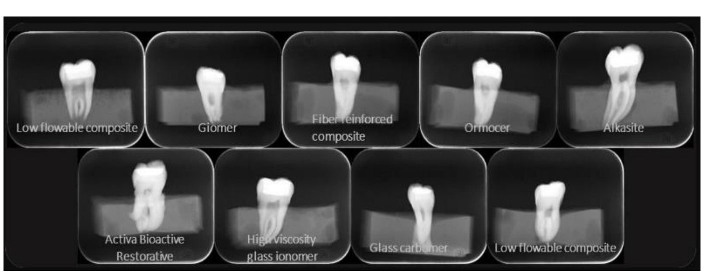

Figure 1. The radiographic images saved in tagged image file format (TIFF)

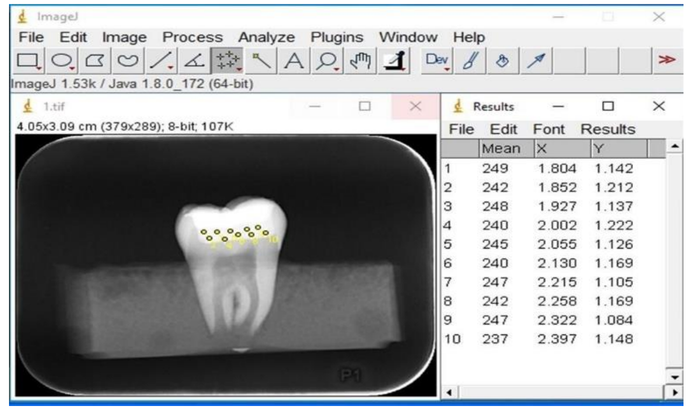

Figure 2. The gray value of each pixel displayed on a scale ranging from 0 (black) to 255 (white)

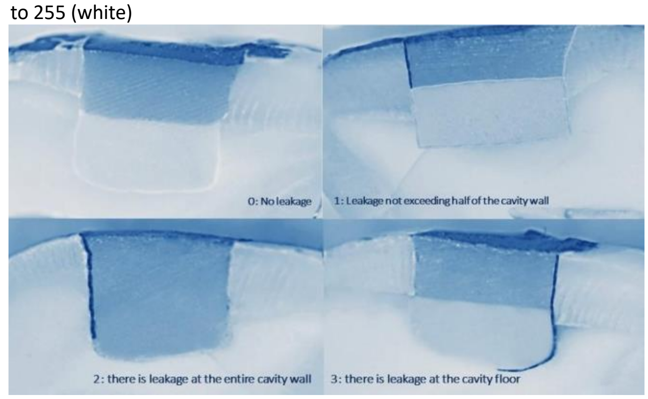

Figure 3. Leakage on the cavity walls at the tooth-restoration interface

Statistical Evaluation

The data were analyzed statistically with SPSS version 26.0 (IBM, SPSS, Statistics, Armonk, NY, USA). A statistical power analysis (G Power calculator) was used to determine the number of samples to be taken per group. Considering that the effect size that could be obtained in the study would be strong hypothetically (f=0.4), it was calculated that 80% power could be reached with 95% confidence when at least 90 teeth (at least 10 teeth for each group) were included in the study.

Conformity to normal distribution was evaluated with the Shapiro Wilk Test. One-way Analysis of Variance was used when comparing normally distributed data between groups, and multiple comparisons were made with the Tukey HSD Test. Pearson Chi-Square Test was used to compare categorical data, and multiple comparisons were made with Bonferroni-corrected Z Test. Results were presented as frequency (percentage) for categorical variables and as mean ± standard deviation and median (minimum-maximum) for quantitative variables. Significance level was taken as $p<0.050$.

RESULTS

Radiopacity results

Distribution of MGVs obtained from different intermediate materials, upper resin composite, dentin and enamel are presented in Table 2. A statistically significant difference was found between the MGV of intermediatives according to the groups (One Way Analysis of Variance, post hoc Tukey HSD Test, $p<0.001$, Table 2).

Alkasite and low-viscosity composite were similar to each other and presented the highest radiopacity values (One Way Analysis of Variance, post hoc Tukey HSD Test, $p<0.001$, Table 2). These groups were followed by high viscosity glass ionomer, ormocer, fiber reinforced composite, giomer, high viscosity composite, bioactive composite and glass carbomer groups, respectively (One Way Analysis of Variance, post hoc Tukey HSD Test, p<0.001, Table 2).

All intermediate materials showed higher radiopacity than the radiopacity of enamel (One Way Analysis of Variance, p<0.001, post hoc Tukey HSD Test, Table 2). Additionally, in the high flowable composite, giomer, fiber reinforced composite, ormocer, bioactive composite, glass carbomer and high viscosity glass ionomer groups, the radiopacity of the material was higher than the radiopacity of the enamel and dentine and was lower than the radiopacity of the upper composite resin (One Way Analysis of Variance, post hoc Tukey HSD Test, p<0.001, Table 2). On the other hand, in the alkasite and the low flowable composite, the radio-pacity of the material was statistically similar to the radiopacity of the upper composite resin (One Way Analysis of Variance, p>0.05, Table 2).

And also, no leakage was detected between the intermediate materials and the overlying composite resin in all groups.

All specimens showed no leakage in the high flowable composite, low flowable composite, and ormocer group. In the giomer and fiber reinforced composite groups, which did not show a statistically significant difference with these groups, leakage was found up to half of the wall in one and two samples, respectively (*P*>.05, Table 3). The five groups showing the lowest microleakage values were followed by the others as follows: Alkasite = High viscosity glass ionomer > Activa bioactive restorative > Glass carbomer groups (Pearson Chi-Square Test, *P*<.001, Table 3). Leakage extending to the cavity floor was detected only in the glass carbomer (Table 3).

Table 2. Comparison of Mean Gray Values (MGVs) by groups.

	High flowable composite	Giomer	Fiber reinforced resin composite	Ormocer	Bioactive Composite	Alkasite	Glass Carbomer	High viscosity glass ionomer	Low flowable composite	p
MGV of material	245,4 ± 1,78^{bC} 245,5 (242 - 248)	247,3 ± 1,06^{bcC} 248 (245 - 248)	248,5 ± 1,96^{cdC} 248,5 (246 - 252)	249,6 ± 0,^{84deC} 250 (248 - 251)	241,6 ± 2,^{01aC} 242 (238 - 245)	255 ± 0^{fC} 255 (255 - 255)	240,4 ± 2,63^{aC} 241 (235 - 244)	251,5 ± 1,43^{eC} 252 (249 - 254)	255 ± 0^{fC} 255 (255 - 255)	<0,001
MGV of Resin Composite	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	255 ± 0^{D} 255 (255 - 255)	---
MGV of Dentin	195,6 ± 1,9^{aA} 195 (193 - 199)	205,7 ± 1,89^{cA} 205,5 (203 - 209)	199,3 ± 2,16^{bA} 199 (196 - 202)	199,9 ± 2,81^{bA} 199,5 (196 - 204)	197,3 ± 1,34^{abA} 197,5 (195 - 199)	197,5 ± 1,51^{abA} 197,5 (196 - 200)	209 ± 1,83^{dA} 209 (206 - 212)	210,4 ± 2,17^{dA} 210 (208 - 215)	210,5 ± 2,27^{dA} 210,5 (207 - 214)	<0,001
MGV of Enamel	214,4 ± 1,58^{aB} 214 (212 - 217)	226,5 ± 2,51^{cB} 226,5 (222 - 230)	214,4 ± 1,26^{aB} 214,5 (212 - 216)	219,5 ± 1,65bB 219 (217 - 223)	214,4 ± 1,43^{aB} 214,5 (212 - 216)	214,3 ± 1,42^{aB} 214 (213 - 217)	226,2 ± 2,2^{cB} 226,5 (222 - 229)	219,5 ± 0,85^{bB} 219,5 (218 - 221)	219,6 ± 1,17^{bB} 220 (217 - 221)	<0,001
p	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001	

One Way Analysis of Variance, post hoc Tukey HSD Test; a-f: There is no difference between groups with the same letter; A-D: There is no difference between GV values with the same letter in each group.

Microleakage

Distribution of microleakage scores obtained from different materials are presented in Table 3. A statistically significant difference was found between the distribution of the microleakage of the materials according to the groups (Pearson Chi-Square Test, post hoc Bonferroni-corrected Z Test, p<0.001, Table 3).

All specimens showed no leakage in the high flowable composite, low flowable composite, and ormocer group. In the giomer and fiber reinforced composite groups, which did not show a statistically significant difference with these groups, leakage was found up to half of the wall in one and two samples, respectively (*P*>.05, Table 3). The five groups showing the lowest microleakage values were followed by the others as follows: Alkasite = High viscosity glass ionomer > Bioactive composite > Glass carbomer groups (Pearson Chi-Square Test, post hoc Bonferroni-corrected Z Test, *p*<.001, Table 3). Leakage extending to the cavity floor was detected only in the glass carbomer (Table 3).

Table 3. Distribution of microleakage scores obtained from different materials.

	NO LEAKAGE	1/2 LEAKAGE	>1/2 LEAKAGE	LEAKAGE IN FLOOR	
MATERIAL	**0**	**1**	**2**	**3**	**p**
High flowable composite	10 (17,2)^{a}	0 (0)^{a}	0 (0)^{a}	0 (0)^{a}	
Low flowable composite	10 (17,2)^{a}	0 (0)^{a}	0 (0)^{a}	0 (0)^{a}	
Ormocer	10 (17,2)^{a}	0 (0)^{a}	0 (0)^{a}	0 (0)^{a}	
Giomer	9 (15,5)^{a}	1 (8,3)^{a}	0 (0)^{a}	0 (0)^{a}	
Fiber reinforced composite	8 (13,8)^{a}	2 (16,7)^{a}	0 (0)^{a}	0 (0)^{a}	**<0,001**
Alkasite	6 (10,3)^{ab}	4 (33,3)^{a}	0 (0)^{a}	0 (0)^{a}	
High viscosity glass ionomer	5 (8,6)^{ab}	5 (41,7)^{a}	0 (0)^{a}	0 (0)^{a}	
Bioactive Composite	0 (0)^{b}	0 (0)^{a}	10 (62,5)^{b}	0 (0)^{a}	
Glass Carbomer	0 (0)^{b}	0 (0)^{a}	6 (37,5)^{ab}	4 (100)^{a}	

Pearson Chi-Square Test, post hoc Bonferroni-corrected Z Test; a-b: There is no difference between groups with the same letter.

DISCUSSION

Radiopacity

A material with sufficient radiopacity allows easy diagnosis of secondary caries under restorations, inadequate marginal adaptation, inappropriate proximal contours, and interface gaps.[14] In the present study, significant differences were found between the radiopacities of different types of base materials. Therefore, the first null hypothesis of the study was rejected.

The radiopacity of resin-based restorative materials most fundamentally depends on the weight and type of fillers. Alkasite and low flowable composite presented significantly higher radiopacity than other intermediates. This can be explained by especially ytterbium trifluoride and higher barium aluminum silicate glass, isophiles, calcium barium aluminum fluorosilicate glass fillers of alkasite and highly silanated barium glass fillers, silanated colloidal silica fillers of low flowable composite. It is reported in the previous studies that the high concentration of high atomic number elements such as ytterbium trifluoride and barium result in more radiopacity in images.[9,15] These groups were followed by high viscosity glass ionomer. The higher radiopacity of glass ionomer than other intermediate resin based materials is based on the 230% radiopacity of Ionostar Plus with its fluoro-alumino-silicate glass structure.

These groups were followed by ormocer (84% silicon dioxide filler), fiber reinforced composite (barium glass fillers 70% by weight, short E-glass fibrils), giomer (Fluoro-boro silicate glass 67.3% by weight), high flowable composite (Barium glass, silica 69% by weight), respectively. Bioactive composite and glass carbomer gave the lowest radioopacity. When previous studies were examined, no study was found that compared the radiopacity of these so many different types of materials. However, very few studies have been found comparing the radiopacity of some of these materials with each other. In one of these studies, ormocer was determined to be more radiopaque than giomer, similar to the findings of the present study.[10] This result was associated with the higher filler percentage of the ormocer. In the study of Yaylacı et al.[8,] similar to our study results, the radiopacity of the giomer was found to be higher than that of high flowable composite. This is thought to be due to the difference in the inorganic components of the giomer and the flowable composite. In different studies, glass carbomer was found to be the material with the lowest radiopacity, similar to the present study.[8,10] Although glass carbomer has similar radiopaque filler content as high viscosity glass ionomer, its low opacity may have been observed due to differences in filler volume and/or size of the materials which does not expressly specified by the manufacturers. Also, the lowest radiopacity value of bioactive composite can be attributed to the its low filler density (56%). And, the fact that the fiber reinforced composite is more radiopaque than giomer and high flowable composite can be explained by the presence of short E-glass fibrils. E-glass short fiber is commonly added reinforced composites. It is a mixture of glass and amorphous phase SiO_2, B_2O_3, Al_2O_3 and other alkali metal oxides.

Studies have shown that the radiopacity of materials equal to or slightly higher than enamel is most appropriate for the diagnosis of secondary caries and accurate evaluation.[10,16] Ideally, radiopacity values should be approximately 200–250%. All the base materials in the present study were within these limits and exhibited higher radiopacity than enamel. Therefore, it can be said that all materials selected as intermediate materials in this study are sufficient in terms of radiopacity.[17] However, excessive radiopacity of the material is also undesirable. This becomes more important in deep restorations as the radiopacity of intermediate materials may tend to accumulate at deeper cavity angles and may lead to radiographic misdiagnosis.[18] The alkasite and low-flowable composite gave similar radiopacity to the overlying composite in this study and these bases did not allow radiographic separation with the overlying nanohybrid posterior resin composite material. When choosing an intermediate material, in terms of radiopacity, it can be said that the material have to be distinguished from the upper material, additionally, have to be similar to enamel or slightly higher may be more suitable.

Other factors that may affect the radioopacity of resin-based materials are the monomer chemistry,[17] thickness[18] and shade[19] of the material, exposure parameters of X-ray radiation[19], the distance of the composite material from the head of the X-ray machine[20] In this study, thickness, shade, distance and exposure parameters were standardized.

One of the limitations of this study was that it is an *in vitro* study. Therefore, the oral environment was not simulated. Radiopacity of materials due to the presence of oral fluids can be changed by factors such as the leakage of fillers such as silicon, barium and strontium into the oral environment. Such studies need to be planned as clinical trials.

Microleakage

Microleakage is the leakage of bacteria, liquid and/or molecules into the inner parts of the tooth through the micro gap formed between the cavity wall and the restorative material. This causes undesirable problems such as secondary caries, post-operative sensitivity, pulpal damage.[21] Polymerization shrinkage in composite resins is one of the main reasons of microleakage. In order to reduce the side effects caused by polymerization shrinkage stress, an intermediate layer between composite resin and dentin has been proposed addition to creating a tooth-restoration interface without gap.[22]

In this study, a Class I cavity preparation was used to assess microleakage due to its high C-factor.[23] And cavity standardization was carried out by a single researcher (BY). In the oral environment, restorations are constantly exposed to thermal and mechanical stresses. These stresses may cause deterioration of the marginal adaptation between tooth and restoration. Therefore, in this study, 10000 thermal cycles, which is corresponding to 1 year of clinical use, were applied to simulate oral conditions.[24] Also, dye penetration is still the most popular technique, although many methods such as radioactive isotopes, scanning electron microscopy, neutron activation analysis, and confocal laser scanning microscopy can be used as test methods to evaluate microleakage.[25]

In the present study, the effect of different types of intermediate materials on microleakage was evaluated. The second null hypothesis of the study was rejected as there was a significant difference between the leakage values obtained from the materials. High flowable composite, low flowable composite, ormocer, giomer and fiber reinforced composite were the most successful groups in terms of microleakage. Among these materials that give the least leakage results, ormocer and fiber reinforced composite are bulkfill materials. The lower microleakage results observed in these bulk replacement materials can be attributed to their lower polymerization shrinkage values. These materials are characterized by their higher inorganic filler content compared to traditional composites. Also, the size and distribution of fillers in bulk replacement materials are optimized to minimize the gaps between particles. This dense packing of fillers reduces the volume available for resin matrix contraction, thus reducing shrinkage. In addition, bulk replacement materials often contain modified resin matrices that have lower viscosity, allowing for better flow and adaptation to cavity walls. Lower viscosity resin matrices can undergo better stress dissipation during polymerization, resulting in reduced shrinkage stress and lower overall shrinkage.[26-28]

Similar to this study, Belli et al. were reported that there was no significant difference in occlusal leakage among the groups when the cavities were lined with a low flowable resin composite or a glass fiber-reinforced composite.[26] In another study, as in the results of this study, ormocer was found to be successful like other flowable composites.[27] On the other hand, unlike the results of this study, in a different study, giomer was found to be unsuccessful when compared with ormocer in terms of microleakage.[28] This result was associated with the chemical structure of ormocer, which allows for lower polymerization shrinkage.

In another study, different from the present study results, microleakage of short fiber reinforced composite base was compared with different flowable composite resins and smart dentin replacement (SDR) material and it was found that it showed the lowest leakage.[29] In our study, fiber reinforced composite resin was not superior to other flowable composites, however, it exhibited the most successful leakage values. This result can be interpreted as short fibers may absorb polymerization shrinkage to some extent and reduce stresses. In this study, it is thought that it is noteworthy that no leakage was found in low-viscosity resin composite, high-viscosity resin composite and ormocer specimens.

In the present study, alkasite and high-viscosity glass ionomer were similar with each other and showed more microleakage than other resin based intermediates, except for the bioactive composite. In the literature, no study was found in which the microleakage of the final restoration was evaluated by applying alkasite, bioactive composite and hybrid glass ionomer as intermediate material. However, in a few studies, cavities were completely restored with one or more of these materials and their microleakage was evaluated. In one of these studies, it was reported that the alkasite showed less leakage than the hybrid glass ionomer, contrary to the current study results.[30] Again in another study, alkasite showed lower leakage than hybrid ionomer.[21] This result was associated with the fact that alkasite may have exhibited low volumetric shrinkage due to the presence of cross-linking methacrylate monomers. It has also been stated that isofillers of the material can act as stress relievers. The different result obtained from our study may be due to the fact that the materials were applied only as intermediate material and the restoration was completed with a nanohybrid composite resin.

And, in the present study, the most microleakage was found in the glass carbomer. Similar to the results of this study, different researchers who compared the microleakage of resin modified glass ionomer, hybrid ionomer, conventional glass ionomer with glass carbomer were stated that they observed the highest leakage in glass carbomer.[22,31,32] The reason for the highest microleakage of glass carbomer may be due to high intensity light curing that may resulted in water evaporation. In addition, the high microleakage of glass carbomer may be interpreted that the glass carbomer may be weaker bonded to dental tissues than other glass ionomer-based materials.

In the present study, no dye leakage was observed between the different base materials and the overlying composite resin. When the studies that have been done are examined, there are some studies evaluating the effect of different bases on the leakage in the enamel and dentin walls of composite resin restorations, while no study investigating the cement and resin composite interface was found. Therefore, this study may be the first conclusion that the leakage proceeds mostly from the enamel and dentin interface.

In this study, adhesive application was performed before the base material placement in all groups with the least microleakage. This may be positively affected the leakage results. In addition, in line with the manufacturer's recommendations, in this present study, pre-placement adhesive system was applied to the alkasite material. This may also be related to the fact that this material presented similar results with the chemically bonded high-viscosity glass ionomer. Studies have shown that the application of alkasite material with adhesive resin reduces microleakage.[24, 33]

There are some limitations in the present study. The first is that this study was not a clinical study and restorations were not performed in the oral environment. In addition, the adhesive and restorative material applied for the final restoration may have an effect on the microleakage values. And, one of the biggest limitations in this study was not adding a group that was finished with the material applied for the final restoration alone without the use of base. However, many factors such as biocompatibility, water solubility, impermeability, ability to bond with the underlying tissue and the upper material are also important in the selection of the appropriate intermediate restorative material. There is a need for more comprehensive studies to include these factors in this regard.

CONCLUSION

Within the results of the present study, a high-viscosity composite, giomer, ormocer and a fiber-reinforced composite can be recommended to be applied under composite resins, since they give successful results in terms of microleakage and present radiographically sufficient radiopacity.

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Hasta Onamı: Bu çalışmada hiçbir hayvan/insan maddesi kullanılmadığından onam formu alınmamıştır.
Hakem Değerlendirmesi: Dış bağımsız.
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Informed Consent: Since there was no animal/human material was used in this study, a consent form was not obtained..
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