NEU PRESS
DİŞ HEKİMLİĞİ DERGİSİ
Vol: 6 Special Issue Year: 2024 Research Article e-ISSN: 2687-5535
https://doi.org/10.51122/neudentj.2024.112

Assessment of the Radiopacity of Different Fissure Sealants Compared to Dental Hard Tissues

Peris CELIKEL[1*] Aybike BAS[2] Fatih SENGUL[3] Sera DERELIOGLU SIMSEK[4]

[1] Asst. Prof., Ataturk University Faculty of Dentistry Department of Pediatric Dentistry, Erzurum, Türkiye, celikelperis@gmail.com

[2] Asst. Prof., Ataturk University Faculty of Dentistry Department of Pediatric Dentistry, Erzurum, Türkiye, aybkbass@gmail.com

[3] Assoc. Prof., Ataturk University Faculty of Dentistry Department of Pediatric Dentistry, Erzurum, Türkiye, fatihs@gmail.com

[4] Prof., Ataturk University Faculty of Dentistry Department of Pediatric Dentistry, Erzurum, Türkiye, simseksera@gmail.com

Article Info

Article History

Received: 23.06.2024
Accepted: 03.09.2024
Published: 15.10.2024

Keywords:
Aluminum Step Wedge,
Digital Dental Radiography,
Fissure Sealant,
Radiopacity.

ABSTRACT

Aim: The radiopacity of dental materials is crucial for assessing the radiographic success of restorations and can significantly influence clinicians' choice of materials. The objective of our study is to compare the radiopacity of five fissure sealants with that of compomer, composite, glass ionomer filling, and dental hard tissues using digital imaging techniques.
Material and Method: Five different fissure sealants (Fuji Triage, BeautiSealant, Grandio Seal, Helioseal F Plus, Embrace Wetbond), compomer (Compoglass F), composite (Solare X), and glass ionomer filling (Equa Forte) materials were prepared as 5 samples each in disk form with a thickness of 2 mm. As controls, sections of primary and permanent teeth with a thickness of 2 mm, along with an aluminum step wedge were utilized. The mean gray values of the samples were measured using Image J software, and the equivalent aluminum thickness was subsequently determined. Statistics analysis using Kruskal-Wallis test at $p<0.05$.
Results: The equivalent aluminum thicknesses related to the radiopacity of fissure sealants are ranked as follows: Fuji Triage (5.2±0.2) > Grandio Seal (3.9±0.2) = permanent tooth enamel (3.7±0.2) = Embrace Wetbond (3.6±0.6) = primary tooth enamel (3.6±0.3) = BeautiSealent (2.1±0.3) > Helioseal F Plus (1.1±0) ($p<0.05$). The radiopacity equivalent aluminum thicknesses of restorative materials are ranked as follows: Compoglass F (7.3±0.4) > Solare X (4.7±0.3) = Equa Forte (4.4±0.4) = permanent tooth enamel (3.7±0.2) = primary tooth enamel (3.6±0.3) ($p<0.05$).
Conclusion: Materials like Fuji Triage and Compoglass F exhibit high radiopacity values, which can significantly aid clinical monitoring and restoration success.

Farklı Fissür Örtücülerin Diş Sert Dokularına Kıyasla Radyoopasitelerinin Değerlendirmesi

Makale Bilgisi

Makale Geçmişi

Geliş Tarihi: 23.06.2024
Kabul Tarihi: 03.09.2024
Yayın Tarihi: 15.10.2024

Anahtar Kelimeler:
Alüminyum kademeli kama,
Dental dijital radyografi,
Fissür örtücü,
Radyoopasite.

ÖZET

Amaç: Dental materyallerin radyoopasitesi yapılan restorasyonların radyografik başarısının belirlenmesinde rol oynamakta ve hekimlerin malzeme seçimini etkileyebilmektedir. Çalışmamızın amacı beş farklı fissür örtücünün kompomer,kompozit, cam iyonomer dolgu ve diş sert dokularına göre radyoopasitesinin dijital teknikle karşılaştırılmasıdır.
Materyal ve Metod: Beş farklı fissür örtücü (Fuji Triage, BeautiSealant, Grandio Seal, Helioseal F Plus, Embrace Wetbond), kompomer (Compoglass F), kompozit (Solare X) ve cam iyonomer dolgu (Equa Forte) materyallerinden 2 mm kalınlığında 5'er adet disk şeklinde örnekler hazırlandı. Kontrol olarak 2 mm kalınlığındaki süt ve daimi diş kesitleri ve alüminyum kademeli kama kullanıldı. Örneklerin ortalama gri değerleri Image J yazılımı kullanılarak ölçüldü ve eşdeğer alüminyum kalınlığı belirlendi. Veriler Kruskal-Wallis testi kullanılarak analiz edildi ($p<0,05$).
Bulgular: Fissür örtücülerin radyoopasitesine ait eşdeğer alüminyum kalınlıkları Fuji Triage (5,2±0,2)> Grandio Seal (3,9±0,2) = daimi diş minesi (3,7±0,2) = Embrace Wetbond (3,6±0,6) = süt dişi minesi (3,6±0,3) = BeautiSealent (2,1±0,3)> Helioseal F Plus (1,1±0) şeklinde sıralanmışlardır ($p<0,05$). Restoratif materyal radyoopasitesine ait eşdeğer alüminyum kalınlıkları ise Compoglass F (7,3±0,4)>Solare X (4,7±0,3) = Equa Forte (4,4±0,4) = daimi diş minesi (3,7±0,2) = süt dişi minesi (3,6±0,3) şeklinde sıralanmıştır ($p<0,05$).
Sonuç: Fuji Triage ve Compoglass F gibi materyaller yüksek radyoopasite değerleri sergilemekte olup, bu özellikleri klinik takip ve restorasyon başarısında önemlidir.

To cite this article: Celikel P, Bas A, Sengul F, Derelioglu-Simsek S. Assessment of the Radiopacity of Different Fissure Sealants Compared to Dental Hard Tissues. NEU Dent J. 2024;6(Special Issue):27-35. https://doi.org/10.51122/neudentj.2024.112

***Corresponding Author:** Peris CELIKEL, *celikelperis@gmail.com*

INTRODUCTION

Preventive dentistry practices have become increasingly important today. These practices encompass various treatments and procedures aimed at maintaining dental health and preventing oral health problems. One of the preventive dentistry procedures frequently applied in clinical routines is fissure sealant application. This procedure is designed to protect potential decay-prone areas on the occlusal surfaces of teeth.[1,2] There are various types of fissure sealants available on the market, categorized by their composition: glass ionomer cement-based, resin-based, polyacid-modified composite resin-based, ormocer-based, giomer-based, and glass carbomer-based.[3] An ideal fissure sealant should hermetically seal pits and fissures, be easy to apply, remain in place for a long time after application, possess thermal and mechanical properties similar to those of enamel, and exhibit appropriate radiopacity.[4]

Appropriate radiopacity is crucial for the long-term follow-up of restorative materials used in dentistry and the success of restorations.[5] Due to the proper radiopacity of dental materials, secondary caries, marginal discrepancies, and faulty proximal contacts between restorations and enamel or dentin can be accurately and easily diagnosed radiographically.[6,7] Materials with either low or excessively high radiopacity can lead to misdiagnosis. For instance, materials with high radiopacity may obscure caries beneath restorations on radiographs.[8] Therefore, the radiopacity level of dental restorative materials should be within a range that allows for clear differentiation from the restored tooth structure.[9]

Secondary caries is one of the primary reasons for replacing restorations.[10] To identify secondary caries beneath restorations radiographically, dental restorative materials must exhibit optimal radiopacity.[11] Therefore, the radiopacity of these materials is a crucial for dentists in preventing failures during postoperative follow-up. Additionally, if dental materials are inadvertently aspirated or swallowed during clinical procedures, their radiopacity becomes essential for accurately locating them.[12]

The radiopacity of dental materials is assessed by comparing their optical density values or equivalent aluminum thickness (measured in millimeters) with those of enamel, dentin, and known aluminum thickness using a reference calibration curve on digital radiographs.[13,14] According to ISO 4049:2019, dental restorative materials designed for use in the crown of a tooth should exhibit a radiopacity equal to or greater than that of aluminum (Al), which is reported to be similar to the radiopacity of dentin when both are of comparable thickness (≥98% purity).[15]

The literature contains numerous studies exploring the radiopacity values of various restorative materials.[10,11,16] However, to the best of our knowledge, there are no studies that specifically investigate the radiopacity of the fissure sealants utilized in our research. Based on this, our study aimed to compare the radiopacities of fissure sealants, which are frequently used in preventive applications in pediatric dentistry, with those of dental hard tissues and other restorative materials commonly used in clinical practice, utilizing digital techniques compared to dental hard tissues and other restorative materials used in the clinical routine with the digital technique. The null hypothesis of this study posits that there is no significant difference in the radiopacity values of the materials used, measured in terms of aluminum thickness (mm).

MATERIAL AND METHODS

The protocol for this study was approved by the Ethics Committee of Atatürk University Medical Faculty in accordance with the Helsinki Declaration (Approval Number: 29 March 2024-2/30). The materials tested in this study were presented in Table 1. Five different fissure sealants were used: Fuji Triage (GC, Tokyo, Japan), BeautiSealant (Shofu, Tokyo, Japan), Grandio Seal (Voco, Cuxhaven, Germany), Helioseal F Plus (Ivoclar Vivadent, Schaan, Liechtenstein), Embrace Wetbond (Pulpdent, Watertown, USA). Additionally, a compomer (Compoglass F (Ivoclar Vivadent, Schaan, Liechtenstein)), composite (Solare X (GC, SouthEast Asia)) and glass ionomer filling (Equa Forte (GC, America)) materials were also used in the study.

Table 1. Type, composition and manufacturers of the materials used in the study

Material	Type	Composition	Manufacturer
Fuji Triage	Fissur Sealant	Fluoro aluminium silicate glass, polyacrylic acid, polybasic carboxylic acid.	GC (Tokyo, Japan)
BeautiSealant	Fissur Sealant	UDMA, TEGDMA, surface pre-reacted glass-ionomer filled fluoroboroalu minum silicate glass, micro silica	Shofu (Tokyo, Japan)
Grandio Seal	Fissur Sealant	70% inorganic fillers in a methacrylate matrix (Bis-GMA, TEGDMA).	Voco (Cuxhaven, Germany)
Helioseal F Plus	Fissur Sealant	Dimethacrylate	Ivoclar Vivadent, (Schaan, Liechtenstein)
Embrace Wetbond	Fissur Sealant	Acrylate ester monomers in two-part, glass-filled	Pulpdent (Watertown, USA)
Compoglass F	Compomer	Aluminium fluorosilicate glass and ytterbium trifluoride	Ivoclar Vivadent, (Schaan, Liechtenstein)
Solare X	Composite	Glass fillers, lanthanoid fluoride nano-particles	GC (SouthEast Asia)
Equa Forte	Glass-ionomer filling	Fluoro-alumino-silicate glass, polyacrylic acid, pigment	GC (America)

The cylindrical teflon molds used in the study for the restorative materials were 2 mm in height with an inner diameter of 8 mm. The manufacturer's instructions were followed to fabricate five specimens of each material. To prevent the formation of an oxygen inhibition layer, Mylar strips were placed on both sides of the specimens after the materials were poured into the molds. Subsequently, the two surfaces of the specimens were polymerized for 20 seconds using an LED light source (Valo Cordless, Ultradent, USA). The samples were then immersed in deionized water and incubated for 24 hours at 37°C.

Using an Isomet Low-Speed Saw 1000 (Buehler, Lake Bluff, IL, USA), sections of a caries-free human third molar removed for orthodontic purposes and a caries-free human third molar nearing natural exfoliation were cut into 2 mm thick sections to obtain enamel and dentin samples as control specimens. The tooth samples were stored in distilled water until they were radiographically evaluated. A digital caliper (Absolute Digimatic; Mitutoyo, Japan) was used to measure the thickness of all specimens, including tooth slices and enamel. To compare the radiopacity of the materials, a reference was employed: a pure aluminum step wedge with incremental thickness in each layer. Specifically, a 100 mm long, 10 mm wide step wedge made of 99.5% pure aluminum was used, starting at 1 mm thickness and increasing by 1 mm increments.

Radiographic procedure

After all specimens were fixed on a cardboard, radiographs were taken using the lateral cephalometric film of a panoramic radiography device (Planmeca ProMax, Finland) (76 kV, 16 mA, 0.4 s).

Measurement of radiopacity value

Using Image J software (National Institutes of Health, Maryland, USA), the mean gray values (MGV) of dentin, enamel, and disc-shaped restorative materials, as well as aluminum stepped wedge, were measured from digital radiography. Five samples of each material were measured, and their mean gray values were averaged (Figure 1). The optical density values (ODV) ranging from 0 to 255 were measured using the software's Intensity Measurement tool. All measurements were conducted by the same individual (FS).

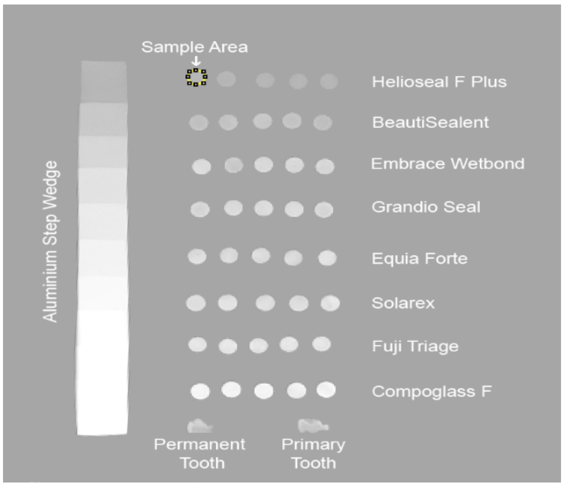

Figure 1. Radiographic images of 2 mm thick tooth sections, dental restorative materials, and aluminum step wedge.

Based on the optical gray density (OGD) readings, the radiopacity values of all investigated materials were converted to millimeter aluminum equivalent (mm Al). To do this, the radiopacity value was determined on the radiograph at each step of the aluminum step wedge, and the mm Al data were acquired by applying the subsequent calculation.[17]

$$\frac{Xx0.5}{Y} + mm$$

$$Al\ below\ materials\ mean\ gray\ value.$$

X = Mean gray value of the material−mean gray value of the step-wedge increment immediately below the material’s mean gray value.

Y = Mean gray value of the step-wedge increment immediately above the material’s mean gray value−mean gray value of the step-wedge increment immediately below the material’s mean gray value.

0.5 = Increment thickness of the step-wedge

Statistical analysis

Prism 9 (GraphPad Software, LLC, USD) was used for statistical analysis. The Kruskal-Wallis test and Dunn's multiple comparison test were applied in the statistical study. A significance level of $p < 0.05$ was used to determine statistical significance.

RESULTS

The mean and standard deviations of the radiopacity values of different dental restorative material, enamel, as well as enamel and dentin samples in terms of aluminum thickness (mm) were presented in Table 2 and Figure 2.

Table 2. Radiopacity values (mean ± standard deviation) of the dental restorative materials used in the study

Group	Mean and SD
Helioseal F Plus	1.1±0 ^{a}
BeautiSealent	2.1±0.3 ^{ab}
Primary tooth dentin	2.4±0.1 ^{ab}
Permanent Tooth Dentin	2.9±0.2 ^{abc}
Primary Tooth Enamel	3.6±0.3 ^{bcd}
Embrace Wetbond	3.6±0.6 ^{bcd}
Permanent Tooth Enamel	3.7±0.2 ^{bcd}
Grandio Seal	3.9±0.2 ^{cde}
Equia Forte	4.4±0.4 ^{def}
Solare X	4.7±0.3 ^{def}
Fuji Triage	5.2±0.2 ^{ef}
Compoglass F	7.3±0.4 ^{f}

SD.: Standart deviation, *The difference between the materials with different letters in the same column is statistically significant (*p*<0.05).

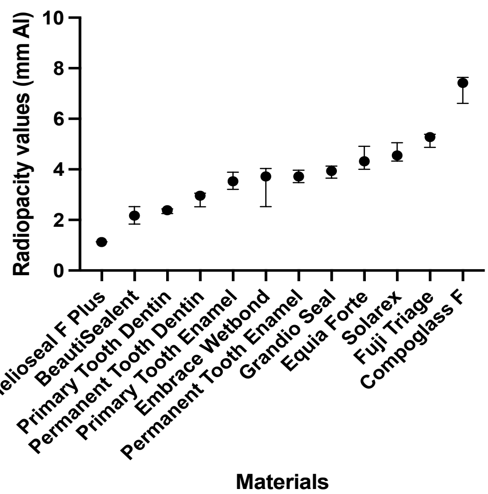

Figure 2. Graph of radiopacity values of materials in terms of aluminum thickness (mm)

The radiopacity values of the materials from largest to smallest are as follows: Compoglass F (7.3±0.4 mm Al), Fuji Triage (5.2±0.2 mm Al), Solare X (4.7±0.3 mm Al), Equia Forte (4.4±0.4 mm Al), Embrace Wetbond (3.6±0.6 mm Al), BeautiSealent (2.1±0.3 mm Al), and Helioseal F Plus (1.1±0 mm Al).

Compoglass F and Fuji Triage materials exhibited higher radiopacity values than permanent and primary enamel and dentin (p<0.05). Helioseal F Plus material had lower radiopacity values than primary and permanent tooth enamel (p<0.05).

DISCUSSION

The radiopacity of dental restorative materials is a crucial property that affects their ability to resist X-rays and their visibility on radiographs. Ensuring sufficient contrast between the restorative material and enamel/dentin is essential for clinical applications, such as identifying improper proximal contours, mismatched marginal edges, and detecting secondary caries.[18,19] Therefore, to ensure proper treatment and clinical follow-up, it is important that restorative materials have appropriate radiopacity, and the radiopacity of all materials used in clinical practice should be thoroughly evaluated.[15]

Based on this information, our study evaluated the radiopacities of different fissure sealants. The results revealed that when comparing the equivalent aluminum thicknesses representing the radioopacity of the fissure sealants, Fuji Triage exhibited higher radioopacity, Grandio Seal, Embrace Wetbond and BeautiSealent demonstrated similar radioopacity. In contrast, Helioseal F Plus showed lower radioopacity compared to both permanent and primary tooth enamel. Therefore, the null hypothesis was rejected. To our knowledge, this study is the first in the literature to compare the radiopacity of various fissure sealants using digital techniques.

It is recommended that the radiopacity of dental restorative materials be compared with pure aluminum and should have similar or greater radiopacity than pure aluminum or dentin of the same thickness because According to ISO 4049 standards, the radiopacity of pure aluminum (99.5%) closely approximates that of human dental dentin.[20,21] Several studies have indicated that to effectively identify secondary caries and defective restorations beneath restorative materials, the radiopacity of these materials should be at least as high as that of enamel tissue.[6,22] The present study, we found that the radiopacity of all materials, except for Helioseal F Plus, was comparable to that of primary and permanent tooth enamel. Based on these findings, it can be concluded that with the exception of Helioseal F Plus, the materials evaluated in our study allow for the radiographic detection of secondary caries and faulty restorations beneath the restorations with the exception of Helioseal F Plus, the materials evaluated in our study allow for the radiographic detection of secondary caries and faulty restorations beneath the restorations.

It has been reported that the level of radiopacity in dental restorative materials is crucial and should be determined according to the specific restorative purpose for which the material is intended.[9,23] Based on this, various dental materials commonly used in the clinical practice, such as composite, glass ionomer fillings, base materials and root canal materials, exhibit different radiopacity values. In a study by Kuter et al.,[24] which evaluated the radiopacity of restorative materials used in pediatric dentistry (including composite, compomer, and glass ionomer cement), it was reported that the posterior composite material had the highest radiopacity values. In another study conducted by Pekkan et al.,[16] it was reported that glass ionomer cements have low radiopacity and should therefore be used with caution in restorative procedures. In our study, the radiopacity of fissure sealants and various restorative materials was evaluated in comparison to enamel and dentin. In the present study, Solare X and Equia Forte exhibited higher radiopacity than dentin, while Fuji Triage and Compoglass showed higher radiopacity than both enamel and dentin. It was also reported that Solare composite had higher radiopacity than dentin, consistent with our results.[25] Additionally, similar studies in the literature report that Equia Forte and Compoglass materials have higher radiopacity than enamel and dentin.[26-29]

It has been reported that glass particles increase the radiopacity of dental materials.[30] This can be explained by the fact that among the materials in our investigation, glass-containing compounds showed the highest radiopacity. Specifically, Compoglass F and Fuji Triage, both of which contain glass, were observed to have the highest radiopacity values among the materials we investigated. Additionally, fissure sealants such as Grandio Seal, Embrace Wetbond, and BeautiSealant exhibit moderate radiopacity due to the relatively small amount of glass fillers they contain within their resin matrices compared to composite materials. On the other hand, the low radiopacity of the Helioseal F Plus fissure sealant may be attributed to its dimethacrylate-based resin structure, which lacks additional radiopaque filler materials.[31]

Upon reviewing the literature, it has been reported that various factors influence the radiopacity of dental restorative materials.[16] These factors include the X-ray beam angle, the distance from the film source, the type of aluminum step wedge, the thickness of the material, its chemical composition, and particle size.[32-34] The difference in radiopacity observed among the materials in our study are likely attributable to variations in their chemical composition.

In this study, a digital radiography system, which provides reliable quantitative data analysis, was used to determine the radiopacity values of the materials.[18] Digital systems offer several advantages over traditional methods, including reduced radiation exposure for both the operator and the patient, instant imaging, and the ability to automatically save images to a computer without the need for chemical processing. They reduce radiation exposure for both the operator and the patient, provide instant imaging, and automatically save images to a computer without the need for chemical processing Additionally, compared to conventional films, digital systems provide higher resolution and a broader range of imaging options, which facilitating easier interpretation of the images. The most significant advantage of digital systems is their ability to standardize repeat radiographic images.[35-37] In digital radiographs, the smallest component of the digital image is pixels. The radiopacity of a material can be assessed by measuring the gray values at specific pixel coordinates using software, which assigns values on a scale from 0 to 255.[38] ImageJ software was utilized to quantitatively measure the radiopacity of the fissure sealant and other samples examined in our study.

In dental treatments, complications such as the accidental swallowing or, worse, the aspiration of hand tools or restorative materials can occur. Therefore, using materials without appropriate radiopacity in dental treatments can pose a safety risk if the material is aspirated during the procedure. The ability of radiopacity to track and localize dental components within soft tissues during traumatic events can be life-saving. This highlights the importance of the radiopacity of materials used in such rare clinical scenarios.

The limitation of this study is the lack of investigation into the effects of moisture and temperature in the oral environment. Factors such as oral fluids, adjacent dental structures, and soft tissues can influence the radiopacity of materials. Further research incorporating simulations of oral conditions and aging processes is necessary.

CONCLUSION

The findings of this study highlight the importance of considering the radiopacity properties of fissure sealants and filling materials used in clinical applications. Within the limitations of this study, the compomer material Compoglass F showed the highest radiopacity value, whereas the fissure sealant Helioseal F Plus exhibited the lowest radiopacity value. In particular, Fuji Triage and Compoglass F stand out with their high radiopacity, which is thought to allow easier radiographic detection of secondary caries and restoration errors. The use of materials with insufficient radiopacity may lead to missed diagnoses of caries and restoration errors. Therefore, it is crucial for dentists to consider radiopacity when selecting materials.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY

The datasets are available from the corresponding author on reasonable request.

Ethical Approval

The protocol for this study was approved by the Ethics Committee of Atatürk University Medical Faculty in accordance with the Helsinki Declaration (Approval Number: 29 March 2024-2/30).

Financial Support

The authors declare that this study received no financial support.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: PC, AB, Data collection or data entry: FS, SDS, Analysis and interpretation: PC, FS, Literature search: PC, SDS, Writing: PC, AB.

REFERENCES

1. Akar M, Alkıs M. An Overview of Pit And Fissure Sealants 2023, in Preventive Dentistry. J Dent Fac Usak Univ.2:36-40.
2. Simonsen RJ. Pit and fissure sealant: review of the literature. Pediatric dent. 2002;24:393-414.
3. Unlugenc E, Bolgul B. Current Fıssure Sealants - Lıterature Revıew. J Dent Fac Atatürk Uni. 2020;30:507-18.
4. Pinkham JR, Casamassimo PS, Henry W, McTigue DJ, Nowak AJ. Pediatric dentistry: infancy through adolescence: 4 th ed. China: Saunders; 1994. 547-50 p.
5. Gul P, Caglayan F, Akgul N, Akgul HM. Comparison of radiopacity of different composite resins. J Conserv Dent. 2017;20:17-20.
6. Yaylaci A, Karaarslan ES, Hatirli H. Evaluation of the radiopacity of restorative materials with different structures and thicknesses using a digital radiography system. Imaging Sci Dent. 2021;51:261-9.
7. Garoushi S, Vallittu P, Lassila L. Mechanical properties and radiopacity of flowable fiber-reinforced composite. Dent Mater J. 2019;38:196-202.
8. Martinez-Rus F, Garcia AM, de Aza AH, Pradies G. Radiopacity of zirconia-based all-ceramic crown systems. Int J Prosthodont. 2011;24:144-6.
9. Pekkan G, Pekkan K, Hatipoglu MG, Tuna SH. Comparative radiopacity of ceramics and metals with human and bovine dental tissues. J Prosthet Dent. 2011;106:109-17.
10. Kopuz D, Ercin O. The radiographic evaluation of 11 different resin composites. Odontology. 2024;112:428-34.
11. Dukic W. Radiopacity of Composite Luting Cements Using a Digital Technique. J Prosthodont. 2019;28:E450-E9.
12. Vyas A, Shah S, Patel N, Yagnik K, Yagnik K. Comparing radiopacity of nanohybrid composite and Giomers: an

in vitro study. Unıversıty Journal Of Dental Scıences. 2022;8.

13. Watts DC, McCabe JF. Aluminium radiopacity standards for dentistry: an international survey. J Dent. 1999;27:73-8.
14. Chan DCN, Titus HW, Chung KH, Dixon H, Wellinghoff ST, Rawls HR. Radiopacity of tantalum oxide nanoparticle filled resins. Dent Mater. 1999;15:219-22.
15. Atala MH, Atala N, Yegin E, Bayrak S. Comparison of radiopacity of current restorative CAD/CAM blocks with digital radiography. J Esthet Restor Dent. 2019;31:88-92.
16. Pekkan G. Radiopacity of dental materials: An overview. AJDR. 2016;8:8.
17. Lachowski KM, Botta SB, Lascala CA, Matosl AB, Sobral MAP. Study of the radio-opacity of base and liner dental materials using a digital radiography system. Dentomaxillofac Radiol. 2013;42:20120153.
18. Hitij T, Fidler A. Radiopacity of dental restorative materials. Clin Oral Investig. 2013;17:1167-77.
19. Espelid I, Tveit AB, Erickson RL, Keck SC, Glasspoole EA. Radiopacity of Restorations and Detection of Secondary Caries. Dent Mater. 1991;7:114-7.
20. Cook WD. An investigation of the radiopacity of composite restorative materials. Aust Dent J. 1981;26:105-12.
21. Lowe RA. OMNICHROMA: One Composite That Covers All Shades for an Anterior Tooth. Compend Contin Educ Dent. 2019;40:8-10.
22. Scotti N, Alovisi C, Comba A, Ventura G, Pasqualini D, Grignolo F, et al. Evaluation of Composite Adaptation to Pulpal Chamber Floor Using Optical Coherence Tomography. J Endod. 2016;42:160-3.
23. Akerboom HB, Kreulen CM, van Amerongen WE, Mol A. Radiopacity of posterior composite resins, composite resin luting cements, and glass ionomer lining cements. J Prosthet Dent. 1993;70:351-5.
24. Kuter B, Uzel I. Comparative radiopacity of pediatric dental restorative materials. Balk J Dent Med. 2022;26:47-51.
25. Tsuge T, Kawashima S, Honda K, Koizumi H, Matsumura H, Hisamatsu N. Radiopacity of anterior and posterior restorative composites. Int Chin J Dent. 2008;8:49-52.
26. Bouschlıcher M, Cobb D, Boyer D. Radiopacity of compomers, flowable and conventional resin composites for posterior restorations. Oper Dent. 1999;24:20-5.
27. Attar N, Tam LE, McComb D. Flow, strength, stiffness and radiopacity of flowable resin composites. J Can Dent Assoc. 2003;69:516-21.
28. Balci M, Turkun L, Boyacıoglu H, Guneri P, Ergucu Z. Radiopacity of posterior restorative materials: a comparative in vitro study. Oper Dent. 2023;48:337-46.
29. Karadas M, Köse TE, Atıcı MG. Comparison of Radiopacity of Dentin Replacement Materials. J Dent Mater Tech. 2020;9:195-202.
30. Prevost AP, Forest D, Tanguay R, Degrandmont P. Radiopacity of Glass Ionomer Dental Materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1990;70:231-5.
31. Azarpazhooh A, Main PA. Is there a risk of harm or toxicity in the placement of pit and fissure sealant materials? A systematic review. J Can Dent Assoc. 2008;74:179-83.
32. Elmowafy OM, Brown JW, Mccomb D. Radiopacity of Direct Ceramic Inlay Restoratives. J Dent. 1991;19:366-8.
33. Tanomaru-Filho M, Jorge EG, Tanomaru JMG, Gonçalves M. Evaluation of the radiopacity of calcium hydroxide- and glass-ionomer-based root canal sealers. Int Endod J. 2008;41:50-3.
34. Turgut MD, Attar N, Önen A. Radiopacity of direct esthetic restorative materials. Oper Dent. 2003;28:508-14.

35. Nomoto R, Mishima A, Kobayashi K, McCabe JF, Darvell BW, Watts DC, et al. Quantitative determination of radio-opacity: Equivalence of digital and film X-ray systems. Dent Mater. 2008;24:141-7.

36. Abreu M, Mol A, Ludlow JB. Performance of RVGui sensor and Kodak Ektaspeed Plus film for proximal caries detection. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2001;91:381-5.

37. Hintze H, Wenzel A. Influence of the validation method on diagnostic accuracy for caries. A comparison of six digital and two conventional radiographic systems. Dentomaxillofac Rad. 2002;31:44-9.

38. Gu S, Rasimick BJ, Deutsch AS, Musikant BL. Radiopacity of dental materials using a digital X-ray system. Dent Mater. 2006;22:765-70.