Comparison of radiopacity of different composite resins

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Abstract
Background: The radiopacity of composite resins has been considered as an important requirement, improving the radiographic diagnosis.

Aim: The present study aimed to compare the radiopacity of eight different composite materials using an aluminum step wedge.

Materials and Methods: Eight different composite resins were used in this study. The samples were prepared using a stainless steel mold (2 × 8), and a 2-mm-thickness horizontal section was obtained from the freshly extracted molar tooth. Three different radiographs were taken by establishing standard conditions. Mean gray values were obtained by taking three measurements from each step of both the tooth and the aluminum step wedge, and the aluminum thickness equivalents were calculated. Statistical analysis was performed using one-way variance analysis and Tukey’s test (P < 0.05).

Results: All aluminum thickness equivalents were found to be higher than those of the enamel and dentin, except Clearfil Majesty Esthetic (2.23 mm ± 0.52 mm) and Filtek Silorane (3.67 mm ± 0.15 mm) (P < 0.05). The Clearfil Majesty Posterior (8.50 mm ± 0.10 mm) and Arabesk Top (8.17 mm ± 0.06 mm) were found to be the most radiopaque composites.

Conclusion: All composite resin materials tested in this study were confirmed to the International Standards Organization 4049 standards. However, since radiopacity is not the only criterion for clinical use, it is a better approach to take all other properties of the materials into consideration.

Keywords: Aluminum thickness equivalents; composite resin; radiopacity

INTRODUCTION

Currently, esthetic restorations are at the forefront of dentistry. Therefore, studies on esthetic restorative materials to compensate material loss in tooth tissues have gained more importance. Teeth color restorations have become popular nowadays because of the development of some materials that have better esthetic and functional features. Dental materials should be sufficiently radiopaque to be detected against a background of enamel and dentin to facilitate correct evaluation of restorations in every region and detection of secondary caries, marginal defects, contour of restoration, contact with adjacent teeth, cement overhangs, and interfacial gaps.

The radiopacity of dental materials used for restorative purposes is especially important for radiographic diagnosis related to posterior teeth. Materials that have sufficient radiopacity provide an opportunity to diagnose repetitive dental caries and also to distinguish dental caries from tooth tissue and restorative material. In adults, almost half of restoration renewals are done because of repetitive dental caries. Because repetitive dental caries usually occurs at the edge of the gingival interface, the detection of this tissue is done using radiography. For this reason, it is extremely important that the composite material presents sufficient radiopacity.

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The degree of radiopacity required for an optimal clinical performance changes depending on the type of material used. Studies on the radiopacity of restorative material generally compare the radiopacity of enamel, dentin, and aluminum. According to some authors, the radiopacity of the restorative material should be equal to or higher than that of dentin. Some authors also think that restorative materials should be of equal or higher radiopacity than radiopacity of enamel. Hitij and Fidler tested 56 dental restorative materials which are commonly used on the gingival part of Class II restoration. The results show that the radiopacity values of all 56 restorative materials were above the dentin reference radiopacity value. Therefore, none of the tested materials could be misinterpreted as dentinal caries on the radiographic image. Saridak et al. compared to the radiopacity of direct and indirect resin composites in different thicknesses using digital image analysis. They found that radiopacity was significantly affected by resin composite type and thickness and also that all composites had higher radiopacity values than dentin.

According to the International Standards Organization (ISO) protocol, the radiopacity of a dental material should be interpreted with either optical density value or equivalent aluminum width (millimeter), which is measured using a reference calibration curve. The radiopacity of the dental materials is recommended to be equal to or higher than that of aluminum, which has the same thickness. Bouschlicher et al. compared the relative radiopacity of enamel, dentin, and 20 resin composite materials used in posterior restorations. Results showed that all composites tested were in accordance with the ISO 4049 guidelines. All of the composites had greater Al equivalents than enamel. Raitz et al. assessed the radiopacity of 28 brands of light-cured composite resins and compared their radiopacity with that of enamel, dentin, and equivalent thickness of aluminum, and they found that all of the materials tested had an equal or greater radiopacity than that of equivalent thickness of aluminum.

This study aimed to compare the radiopacity of eight different composite materials using aluminum step wedge.

**MATERIALS AND METHODS**

In this study, eight different composite resins were used [Table 1]. The samples \( n = 3 \) were prepared using a stainless steel mold of 2-mm thickness and 8-mm diameter. They were kept in distilled water for 24 h before the radiographic process. The tooth material for the enamel/dentin specimen was extracted due to periodontal problems as approved by the Ethics Committee of the School of Dental Medicine. A 2-mm enamel/dentin specimen was prepared by horizontal sectioning of a freshly extracted molar using a slow-speed Isomet 1000 (Buehler, IL, USA) diamond saw with a constant speed of 250–300 rpm. The tooth specimen was then stored in tap water until use.

The composite samples and human tooth slice together with an aluminum step wedge, which had 10-step (with 1.5-mm increase in each step), were placed intraoral occlusal film in eight groups (Kodak Ultra-speed Dental; Corestream Health, Inc., France). The step wedge was fabricated by riveting together ten 1.5-mm thick plates of aluminum alloy (purity of 99.5% Al). The plates were 10 mm wide, and the aluminum wedges ranged from 1.5 to 15-mm thick. Radiography was obtained at 60 kVp, 7 mA using an X-ray device (Belmont Dental X-ray, 303A, UK). The focal length was set at 15 cm, and the exposure time was 0.5 s. The photographic process was performed using an automatic processing machine (Velopex Extra-x, Medivance Instrument, UK). By establishing standard conditions, three radiographs were taken. These films were scanned (Epson Perfection 3200 Photo; Seiko Epson, Japan) and saved in TIFF format [Figure 1]. Three different areas were selected on the enamel and dentin at each step of the aluminum step wedge on each film, composite samples, and tooth section. The mean gray values were calculated using the histogram function of a commercial computer program (Adobe Photoshop CS3; Adobe Systems Inc., CA, USA). Taking three measurements from composite samples, teeth, and each step of the aluminum step wedge, the mean gray values were obtained. Three logarithmic equations were obtained by performing a simple regression analysis on each value, and the radiopacity of each sample was converted into millimeters aluminum equivalent by placing the gray values into these logarithmic equations. By following these steps, the radiopacities of the materials were calculated in terms of aluminum equivalent.

Statistical analysis was performed using one-way variance analysis and Tukey’s test \( (\alpha = 0.05) \).

**RESULTS**

Test materials and the measured aluminum thickness equivalents are given in Table 2. Some statistical differences were found at the end of the variance analysis applied to aluminum thickness equivalents of test materials \( (P < 0.05) \) [Table 2]. All aluminum thickness equivalents were found to be higher than those of the enamel \( (4.53 \text{ mm} \pm 0.35 \text{ mm}) \) and dentin \( (2.43 \text{ mm} \pm 0.21 \text{ mm}) \), except the Clearfil Majesty Esthetic \( (2.23 \text{ mm} \pm 0.52 \text{ mm}) \) and Filtek Silorane \( (3.67 \text{ mm} \pm 0.15 \text{ mm}) \) \( (P < 0.05) \). The Clearfil Majesty Posterior \( (8.50 \text{ mm} \pm 0.10 \text{ mm}) \) and Arabesk Top \( (8.17 \text{ mm} \pm 0.06 \text{ mm}) \) were found to be the most radiopaque composites [Table 2].

**DISCUSSION**

An appropriate radiopacity is an important need for restorative materials because important color quality indicators, such as light penetration and reflection degree,
are regulated according to the radiopacity.\textsuperscript{[15]} Radiopacity makes the diagnosis of repetitive dental caries between enamel/dentin and restorative material, erroneous proximal contours, and inappropriate marginal edges easier.\textsuperscript{[16,17]} One of the main reasons to change restorations is repetitive dental caries.\textsuperscript{[18]} Therefore, restoration materials should have the optimal radiopacity, which makes the teeth–restoration interface easier to distinguish from the tooth structure.\textsuperscript{[4]} Salzedas et al.\textsuperscript{[19]} stated that knowledge of radiopacities of materials may help dentists select the correct restorative material during treatment. They also indicated that materials with low radiopacities may cause misdiagnosis of the defects in radiography. For this reason, they stated that middle-level radiopacity is preferred to evaluate the radiography.\textsuperscript{[5,16]}

Recently, the ISO defined the radiopacity standards that dental materials need to have. According to the ISO 4049, restorative materials applied to coronal tooth tissue should have either similar or higher radiopacity than the same thickness of pure aluminum. It is also very clear in the ISO 4049 that the lowest radiopacity value of the restorative materials should be the same as the radiopacity value of the dentin of the same thickness.\textsuperscript{[20]} In the present study, all used materials showed more radiopacity than that of dentin, thus conforming to the ISO standards.

The radiopacity of restorative materials may change according to the variety and amount of the fillers added to the material (silver, zinc, barium, and strontium).\textsuperscript{[7,21]} Turgut et al.\textsuperscript{[8]} demonstrated that when monomers in the resin composite content give a radiolucent view, the fillers show different opacity values. The main reason behind these differences in the radiopacity of the materials is the difference in their contents.

| Table 1: Details of the investigated restorative materials |
|----------------------------------------------------------|
| **Product** | **Manufacturer** | **Type** | **Organic matrix** | **Fillers** | **Content** | **Particle size** | **Filler load percentage (weight; volume)** | **Lot number** |
|---------------|-----------------|---------|-------------------|-------------|------------|-----------------|--------------------------------|---------------|
| Clearfil Majesty Esthetic | Kuraray Medical, Okayama, Japan | Nanohybrid | Bis-GMA, hydrophobic aromatic dimethacrylate | Silanated barium glass, filler, prepolymerized nano-organic filler | 0.7 μm, 20 nm | 78; 66 | 00034A |
| Clearfil Majesty Posterior | Kuraray Medical, Okayama, Japan | Nanohybrid | Bis-GMA, TEGDMA, hydrophobic aromatic dimethacrylate | Silanated glass ceramic filler, surface-treated alumina microfiller | 1.5 μm, 20 nm | 92; 82 | 00110A |
| Grandio | VO Can GmbH, Cuxhaven, Germany | Nanohybrid | Bis-GMA, TEGDMA, UDMA | Glass-ceramic (microfiller) | 1 μm, 20-60 nm | 87; 71 | 1117206 |
| Grandio Flow | VO Can GmbH, Cuxhaven, Germany | Flowable | Bis-GMA, TEGDMA | SiO2 (nanofiller) | Quartz, yttrium fluoride | 0.47 μm | 76; 55 | 1127403 |
| Filltek Silorane | 3M ESPE, ABD | Silorane | Siloranes | Silicon dioxide, glass ceramic particles | Glass ceramic 1 μm, SiO2 - (40 nm) | 80; 65 | 1132573 |
| Admira | VO Can GmbH, Cuxhaven, Germany | Ormocer | Ormocer, Bis-GMA, UDMA | Ba-Al-B-silicate glass | 0.7 μm | 78; 56 | 1034200 |
| Arabesk Top | VO Can GmbH, Cuxhaven, Germany | Microhybrid | Bis-GMA, TEGDMA, UDMA | Barium and Lithium aluminum silicate glass | 0.7 μm | 77; 56 | 1051274 |
| Valux Plus | 3M ESPE, USA | Hybrid | Bis-GMA, TEGDMA | Silane treated ceramic | 0.01–3.5 μm | 80; 71 | N252857 |

Bis-GMA: Bisphenol A-glycidyl methacrylate, UDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate

| Table 2: Statistical comparison results of the aluminum thickness equivalents among all test materials |
|----------------------------------------------------------|
| **Test materials** | **Aluminum thickness equivalents (mm)** | SD | F | P |
|---------------------------|---------------------------------|----|---|---|
| Clearfil Majesty Esthetic | 2.23\textsuperscript{a} | 0.25 | 361.034 | 0.001 |
| Clearfil Majesty Posterior | 8.50\textsuperscript{f} | 0.10 | | |
| Grandio | 6.87\textsuperscript{e} | 0.12 | | |
| Grandio Flow | 5.67\textsuperscript{e} | 0.15 | | |
| Filltek Silorane | 3.67\textsuperscript{b} | 0.15 | | |
| Admira | 5.37\textsuperscript{e} | 0.15 | | |
| Arabesk Top | 8.17\textsuperscript{f} | 0.06 | | |
| Valux Plus | 5.87\textsuperscript{e} | 0.25 | | |
| Enamel | 4.53\textsuperscript{e} | 0.35 | | |
| Dentin | 2.43\textsuperscript{e} | 0.21 | | |

Same superscripts in same column represent statistical differences. SD: Standard deviation

Figure 1: A digital film view that includes test materials and aluminum step wedge. (1) Clearfil Majesty Esthetic, (2) Clearfil Majesty Posterior, (3) Grandio, (4) Grandio Flow, (5) Filltek Silorane, (6) Admira, (7) Arabesk Top, (8) Valux Plus
The content of the restorative materials is always changed to be able to provide a sufficient clinical radiopacity. Adding some chemical elements with a high atomic number, such as zinc, strontium, zirconium, barium, and lanthanum, to the restorative materials provides the opportunity to produce more radiopaque materials\(^{[5,6]}\). Sabbagh et al.\(^{[22]}\) demonstrated a linear relationship between the percentage weight of the filler and radiopacity using the Digora digital system.

In this study, all aluminium thickness equivalents were found to be higher than those of the enamel (4.53 mm \(\pm 0.35\) mm) and dentin (2.43 mm \(\pm 0.21\) mm), except the Clearfil Majesty Esthetic (2.23 mm \(\pm 0.52\) mm) and Filtek Silorane (3.67 mm \(\pm 0.15\) mm) \((P < 0.05\)). The Clearfil Majesty Posterior (8.50 mm \(\pm 0.10\) mm) \((P < 0.05)\) and Arabes Top (8.17 mm \(\pm 0.06\) mm) were found to be the most radiopaque composites. When one looks at the content of the materials, the weight percentages of the fillers appear close to each other; however, different contents may be the reason behind having different radiopacities. When the radiopacities of the dental composites are 70% higher than the filler volume and the percentage of the radiopaque oxides is higher than 20%, a higher radiopacity appears on the enamel\(^{[23]}\). A large increase in the percentage of the metal oxides may disrupt composite resin, or barium and strontium ions may disrupt aluminosilicate mesh, and this may be a disadvantage\(^{[24,25]}\).

In the present study, the radiopacity analysis of the restorative materials was done using a digital image analysis method. The evaluation done using the digital image analysis program was more effective than that done using a classical radiographic densitometer. Composite resin materials can be distinguished from dental caries using a classical radiographic densitometer. Gürdal and Akdeniz\(^{[26]}\) stated that the digital image analysis done using the histogram function works better in clinical use for detecting small changes in the radiographic density. This finding was also confirmed by other studies\(^{[27]}\).

**CONCLUSION**

All composite resin materials tested in this study confirmed to the ISO 4049 standards. It is important for the material to be radiopaque to detect dental caries. However, since radiopacity is not the only criterion for clinical use, it is a better approach to take all other properties of the materials into consideration.

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**Conflicts of interest**

There are no conflicts of interest.

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