Radiopacity of bulk fill flowable resin composite materials

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Abstract

Objectives: The purpose of this study was to evaluate the radiopacity of currently marketed bulk fill flowable dental composite materials (Beautifil Bulk Flowable, SDR Flow, Filtek Bulk Fill Flow, and x-tra Base Bulk Fill).

Materials and Methods: Six specimens of each material with a thickness of 1 mm were prepared, and digital radiographs were taken, using a CCD sensor along with an aluminum stepwedge and 1 mm-thick tooth slice. The mean gray level of each aluminum stepwedge and selected materials was measured, using the equal-density area tool of Kodak Dental Imaging software. The equivalent thickness of aluminum for each material was then calculated by using the stepwedge values in the CurveExpert version 1.4 program.

Results: The radiopacity of bulk fill flowable composites sorted in descending order as follows: Beautifil Bulk Flowable (2.96 mm Al) = x-tra base bulk fill (2.92 mm Al) = SureFil SDR Flow (2.89 mm Al) > Filtek Bulk Fill Flow (2.51 mm Al) ($P < 0.05$).

Conclusions: As all materials had a radiopacity greater than dentin and enamel; their adequate radiopacity will help the clinicians during radiographic examination of restorations.

Clinical Significance: Bulk fill composite materials have greater radiopacity, enabling clinicians to distinguish the bulk fill composites from dentin and enamel.

Key words: Bulk-fill flowable, composite, radiopacity

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Introduction

Resin composite materials have been improved significantly since they were first introduced more than a half century ago,[1] and current resin composite materials exhibit clinical success comparable to or higher than that of dental amalgam.[2,3] These materials are widely used in dentistry for their aesthetic and mechanical properties, which closely resemble those of natural teeth, and for their excellent adhesion to dental hard tissues.[4] However, the major disadvantage of current resin composite restoratives is the incremental placement technique required to reduce polymerization stress and to ensure complete depth of cure on light irradiation.[5]

Flowable resin restoratives can be used to address some of the challenges created for dentists by placement of higher viscosity universal or posterior composites. Flowable composites have the good wetting capacity and greater ease of insertion, which helps adaptation to cavity walls

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when they are used as liners.[6,7] However, the first flowable composites were not a suitable choice for composite restoration because of their poorer mechanical properties and high volumetric shrinkage, due mainly to the lower filler content.[6,8]

To simplify the placing procedure for composite materials, one of the latest trends in dental materials research is the development of flowable composite materials that can be placed in bulk up to a thickness of 4 mm. Recently, several posterior bulk fill flowable composite materials with the more favorable mechanical properties than those of conventional flowable composites were introduced by a number of manufacturers. Although it was reported that bulk fill flowable composites had mechanical properties similar to those of conventional composites,[9] previous studies reported that when bulk fill flowable resin composite restoratives were placed in a single 4 mm increment, marginal adaption,[10] and bond strength[11] to dentin were uninfluenced by bulk placement.

Radiopacity is one of the essential properties of all restorative materials. According to the International Standards Organization for Standardization (ISO 4049), the radiopacity of such materials should be equal to or greater than the same thickness of aluminum and should not be <0.5 mm of any value claimed by the manufacturer.[12] Radiopacity must differ sufficiently from tooth tissue to be capable of being distinguished, and the restorative material must also be radiopaque enough to be distinguished from a void.[13] Adequate radiopacity of the material allows the clinician to differentiate secondary caries formation from restoration and surrounding tooth structure, to evaluate and detect voids, overhangs and open margins, and to locate dental pulp on radiographs.[14] In addition, studies conclude that, for optimum contrast, a restorative material with a radiopacity slightly greater than or equal to that of enamel is ideal for the detection of secondary caries in radiographs.[15,16]

Although a number of studies have been conducted on the radiopacity of composite materials, at the time of this study, there was no report in the literature on the radiopacity of bulk flow composite restoratives, and dentists must, therefore, rely on manufacturers' data. As it has been shown, these data were not always reliable,[17] the aim of the present study was to evaluate the radiopacity of bulk fill flowable composite materials by using a digital radiography system.

Materials and Methods

Specimen preparation

The materials evaluated in the present study were comparatively new, commercially available bulk fill flowable dental composite materials. The materials used are shown in Table 1. Four holes, 1 mm in depth, and 5 mm in width were prepared on the plastic plates, 1 mm in thickness by using a puncher. After filling the holes on the plate with a material, a glass slide was used to cover the surface of each material to flatten the surface and to force out any excess material. Specimens were polymerized by use of an LED curing device (Elipar Freelight 2: 3M ESPE, St. Paul, USA) with a power of 1000 mW/cm^2 for 10 s. By this way, six composite discs, 1 mm in depth, and 5 mm in width were prepared for each group. Specimens with macroscopic defects (i.e., voids, cracks) were excluded from the study, and new specimens were prepared as previously described.

The thickness of each specimen was measured using a digital caliper (Mitutoyo, Tokyo, Japan) to obtain 1 mm thickness, and 600- and 1.000-grit silicon carbide papers were also used for this purpose. All bulk fill specimens were stored dry and in darkness at room temperature for 24 h prior to the performance of radiopacity measurement.

Noncarious human third molars were used for the enamel/dentin specimens. A specimen, 1 mm in thickness of was prepared by longitudinal sectioning of a third molar, using a slow-speed diamond saw (Micracut 151, Metkon, Bursa, Turkey) with a constant speed of 250–300 rpm.

Radiopacity evaluation

Digital radiographic images of the specimens were acquired by use of a Kodak digital sensor (Eastman Kodak Co., Rochester, NY) together with an aluminum stepwedge with variable thickness (from 1 to 14 mm, in 1 mm increments) and tooth slice. A Kodak 5100 intraoral X-ray unit was used, operating at 60 kV, 7 mA, and 0.20 s. The object-to-focus distance was 30 cm. Standardization of the focus-to-film distance (30 cm) and the 90° angle positions of both the digital RVG sensor and head of the X-ray machine were performed similar to Carvalho-Junior's contrivance [Figure 1].[18]

The mean gray value of each aluminum stepwedge and selected materials was measured by outlining a region of interest, using the equal-density area tool of Kodak's Dental Imaging software version 6.12.32.0 (Eastman Kodak Co., Rochester, NY) [Figure 2]; regions were selected by avoiding areas containing air bubbles inside the material. This procedure was repeated 5 times for each specimen and aluminum stepwedge, and the average was calculated. The mean gray value of the material was then converted to millimeters of aluminum equivalent, using the CurveExpert version 1.4 program (Hyams D.G., Starkville, MS, USA). The measurement was undertaken by one operator, and the operator was blinded to the identity of the materials.

Statistical analysis

The distribution of radiopacity data were primarily analyzed for normal distribution using the Kolmogorov–Smirnov test and for equal variance using the Levene test. Although radiopacity data were normally distributed, group variances were not equal, and nonparametric tests (Kruskal–Wallis test and Mann–Whitney U-test) were used to compare mean radiopacity across different groups. The statistical analyses were performed using SPSS version 18 software (SPSS Inc., Chicago, IL, USA). The level of significance was set at $P = 0.05$.

Results

Table 2 and Figure 3 show the mean radiopacity values of the evaluated materials, which were as follows: Beautifil Bulk Flowable (2.96 ± 0.1 mm Al) = x-tra base bulk fill (2.92 ± 0.1 mm Al) = SureFil SDR Flow (2.89 ± 0.1 mm Al) > Filtek Bulk Fill Flow (2.51 ± 0.2 mm Al). All bulk fill flowable composites had significantly greater radiopacity values than the dentine and enamel ($P < 0.05$). There were no significant differences among radiopacity values of SureFil SDR Flow, Beautifil Bulk Flowable, and x-tra base bulk fill, but the radiopacity of these materials was significantly higher than that of Filtek Bulk Fill Flow ($P < 0.05$) [Figure 3].

Table 1: Materials use in the present study

Materials	Filler% (wt/vol)	Composition
SureFil SDR Flow (Dentsply, Konstanz, Germany) Lot: 110291	64/44	Filler: Ba-Al-F-B-Si glass and St-Al-F-Si glass as fillers Resin matrix: Modified UDMA, TEGDMA, EBPDMA
Beautifil Bulk Flowable (Shofu, Kyoto, Japan) Lot: 071402	73/60	Filler: F-Al-Si glass Resin matrix: Bis-GMA, Bis-MPEPP, TMGDMA
Filtek Bulk Fill Flow (3M ESPE, Seefeld, Germany) Lot: N657914	64.5/42.5	Filler: Zirconia/silica, ytterbium Trifluoride Resin matrix: Bis-GMA, UDMA, Bis-EMA, Procrylat resins
X-tra Base Bulk Fill (Voco, Cuxhaven, Germany) Lot: 1445154	75/61	Filler: NA Resin matrix: Bis-GMA, UDMA

NA=Not available, Bis-EMA=Bisphenol-A polyethylene glycol diether dimethacrylate, Bis-GMA=Bisphenol-A diglycidyl ether dimethacrylate, Bis-MPEPP=Bisphenol-A-Polyethoxy-Dimethacrylat, EBPDMA=Ethoxylated Bisphenol-A-dimethacrylate, TEGDMA=Triethylene glycol dimethacrylate, UDMA=Urethane dimethacrylate, TMGDMA=Tetramethylene glycol dimethacrylates

Table 2: Radiopacity of bulk-fill flowable composite materials

Material	Mean (SD) (mm eq AL)	Subset[a]	Radiopacity declared by the manufacturer
Beautifil bulk flowable	2.96±0.1	a	2.5 mm Al
X-tra base bulk fill	2.92±0.1	a	3.5 mm Al
SureFil SDR flow	2.89±0.1	a	2.2 mm Al
Filtek bulk fill flow	2.51±0.2	b	2.4 mm Al
Dentin	1.09±0.0	c	
Enamel	1.84±0.0	d	

[a]Subsets demonstrating similar means (P<0.05)

Discussion

Restorative materials should ideally be radiopaque to enable visualization and assessment by radiograph, and all newly developed materials should, therefore, be investigated in this respect.[19] Bulk fill flowable resin composite restoratives

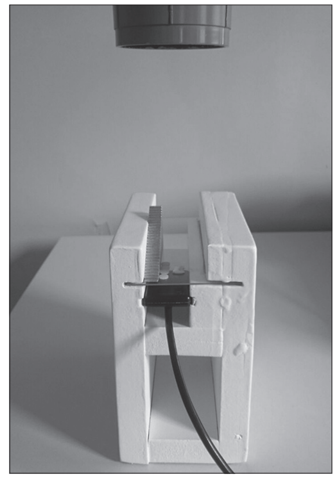

Figure 1: Front view of experimental set-up, which keeps the head of the X-ray central beam at 30 cm and at a 90° angle to the surface of CCD sensor

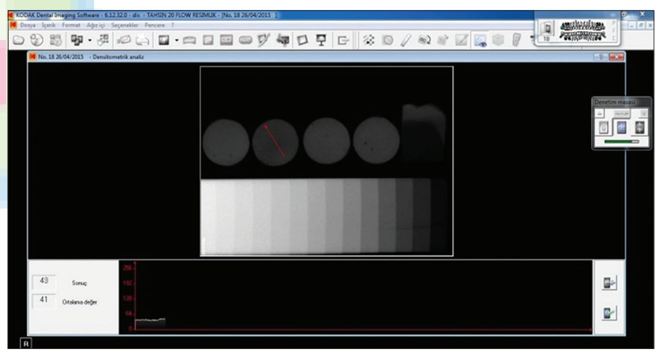

Figure 2: Screen image of computer during measurement of radiopacity of materials by Kodak Dental Imaging Software version 6.7 (Eastman Kodak Co., Rochester, NY)

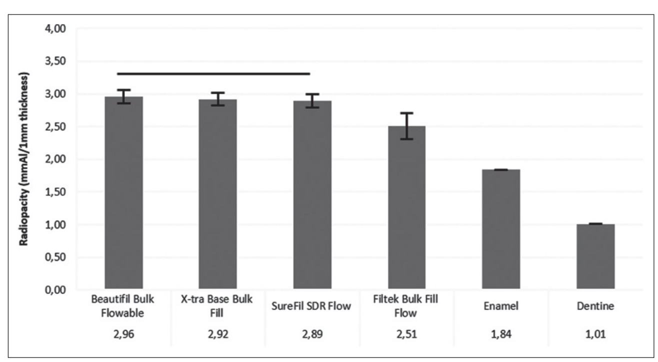

Figure 3: Mean (standard deviation) radiopacity of bulk fill flowable dental composite materials, compared to dentin and enamel. (Horizontal bars indicate that means are not significantly different from each other) (P < 0.05)

are relatively new to the market, but until date there are no reports in the literature about the radiopacity of these materials. For that reason, four currently available bulk fill flowable composite restoratives were evaluated in this study.

The results show that the radiopacity values of all the tested materials were greater than those of enamel and dentin, which means that none of the tested materials could be misinterpreted as dentinal caries on the radiograph. Previous studies have concluded that restorative materials with a radiopacity slightly greater than or equal to enamel is ideal for the detection of secondary caries in radiographs; these materials fulfilled this requirement and can, therefore, be used in restorative applications.[20,21]

The reported radiopacity values of bulk fill flowable resin composite are limited in the literature, therefore, dentists have rely on only manufacturer given information. The manufacturers provided exact radiopacity values for all the tested materials were shown in Table 1. Comparing the results of this study with the radiopacity values as declared by the manufacturers, it can be seen that the value for Filtek Bulk Fill Flow accord with our results. However, there are noticeable differences between our results and the manufacturers' radiopacity values for x-tra base bulk fill (2.92/3.5 mm Al), Beautifil Bulk Flowable (2.96/2.5 mm Al, and SureFil SDR Flow (2.89/2.2 mm Al). One of the requirements of ISO 4049 is that the radiopacity of any material should not be <0.5 mm of any value claimed by the manufacturer. It follows that dentists should not rely on the radiopacity values declared by manufacturers (as also previously reported in the literature).[17] Nevertheless, x-tra base bulk fill was found to have clinically acceptable higher radiopacities than enamel and dentin. Materials with a radiopacity close to that of dentin may present a clinical challenge for dentists during radiographic examination of restorations.

The use of 99.5% pure aluminum is currently specified when testing under the ISO Standard 4049.[12] However, it is also advisable to use secondary standards for enamel and dentin.[22] The dentin and enamel reference radiopacity values used in the present study were 1.09 ± 0.0 and 1,84 ± 0.0 mm Al, respectively. The values of enamel and dentin are in agreement with previous studies, where dentin radiopacity was close to 1 mm Al and enamel radiopacity was close to 2.0 mm Al.[23-25]

In the present study, a digital radiographic system was used as it reduces the operator's (and patient's) exposure to radiation, eliminates the need for film development chemicals, offers higher resolution and greater dynamic range than X-ray film, and facilitates image analysis. Most importantly, the digital system ensures consistent radiograph development;[13,26] traditional film development, unless performed carefully, can produce the significant variations in the final radiograph.[26]

Conclusion

All the tested bulk fill flowable composite materials recorded greater radiopacities than enamel and dentin. It can be concluded that these composites would not hamper radiographic examination of restorations and can be used in restorative applications. However, the evidence indicates that radiopacity data provided by manufacturers cannot be relied on in every case.

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Conflicts of interest
There are no conflicts of interest.

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