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Comparative Radiopacity of Six Flowable Resin Composites

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Clinical Relevance

Flowable resin composites ranged in radiopacity from dentin equivalence to greater than that of enamel, making the product selection an important consideration for achieving adequate diagnostic contrast.

SUMMARY

Objective: This study investigated the radiopacity of six commercially available flowable composites by using a digital image analysis method to determine the mean gray values of the materials.

Methods: The flowable resin composites evaluated in this study were Clearfil Majesty Flow, Estelite Flow Q, Tetric N Flow, Esthet X Flow, Filtek Supreme XT Flow and Gradia Direct LoFlo. Ten sample discs (6 x 1 mm) for each group were prepared and 1-mm thick slices were obtained from freshly-extracted teeth for the control group. The mean gray values (MGVs) of each specimen and aluminum (Al) stepwedge were measured by using the histogram function of a computer graphics program. Analysis of variance (ANOVA) was used to investigate the significance of the differences among the groups. For pairwise comparisons, the Tukey test was applied (α=0.05).

Results: The radiopacity values of Gradia Direct LoFlo, dentin and Estelite Flow Q were close to that of 1 mm Al. Tetric N Flow and Cl Majesty Flow were more radiopaque than enamel, whereas Filtek Supreme XT Flow had a similar radiopacity to enamel.

Conclusion: The radiopacity of flowable composites varies considerably, and care must be taken when selecting an appropriate material to enable secondary caries detection under posterior composite restorations.

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DOI: 10.2341/09-340-L

INTRODUCTION

Radiopacity is an essential property for all restorative materials,[1] because adequate radiopacity allows the clinician to evaluate restoration integrity at subsequent recall appointments, distinguishes caries from restorative material and surrounding tooth structure on radiographs and detect voids, overhangs and open margins.[1-5]

The question of how a radiopaque restorative material should function for optimal diagnostic utility has been investigated by several authors. Radiopacity is usually determined in comparison with enamel, dentin or aluminum.[3] It was demonstrated that the radiopacity of dentin was approximately equivalent to that of aluminum (Al) of the same thickness and that enamel has approximately twice the radiopacity of Al with the same thickness.[6] Most studies conclude that, for optimum contrast, a restorative material with a radiopacity slightly greater than or equal to enamel is ideal for the detection of secondary caries in radiographs.[3,20-21] It is widely recognized that unfilled resin adhesives are radiolucent and that the use of thick layers of such materials can present a diagnostic challenge on subsequent radiographs.[2,4]

On the other hand, according to the *International Standardization Organization* (ISO),[7] a resinous dental material should be at least as radiopaque as the same thickness of pure Al. In the American Dental Association's (ADA) Specification #27, the ADA also recommends that these materials should present a radiopacity equivalent to 1 mm Al, which is approximately equal to that of natural tooth dentin.[8]

Flowable resin composites were introduced in 1996 to meet the need for a composite material with special handling characteristics.[1] Due to their higher flow, which is the result of less filler loading in their formulation, these composites provide easier insertion, better adaptation, and greater elasticity.[2,4]

There are several studies on the radiopacity of composites in the literature; however, few studies regarding the radiopacity of low-viscosity composites are available. Currently, most radiopaque dental resin composites rely on the use of heavy-metal glass fillers to impart radiopacity,[3-5] but it is reported that the radiopacity of some flowable resin composite materials used beneath posterior restorations is lower than desirable.[2] Thus, the current study investigated the radiopacity of six commercially available flowable composites by using the digital image analysis method to determine the mean gray values of materials.

METHODS AND MATERIALS

Sample Preparation

The flowable resin composites evaluated in the current study were Clearfil Majesty Flow (Kuraray Medical Inc, Okayama, Japan), Estelite Flow Q (Tokuyama Dental, Tokyo, Japan), Tetric N Flow (Ivoclar Vivadent AG, Schaan, Liechtenstein) Esthet X Flow (Dentsply DeTrey, Konstanz, Germany), Filtek Supreme XT Flow (3M ESPE, St Paul, MN, USA) and Gradia Direct LoFlo (GC Corp, Tokyo, Japan). Stainless steel ring molds with a 6-mm internal diameter and 1-mm depth were used to prepare the specimens as suggested by ISO standard 4049.[7] The mold was placed on a glass slab and the resin composites were placed in the mold until the mold was overfilled, then a Mylar strip was placed on the top. A second glass slide 1-2 mm thick was then placed over the strip to flatten the surfaces before curing with a light-activating source (Demetron LC, Orange, CA, USA; light intensity 450 mW/cm^2). The specimens of each material were cured for 40 seconds through the Mylar strip and glass slide. After every five samples, light output was checked using a photometric tester (Dentek, Inc, Buffalo, NY, USA) that exceeded 400 mW/cm^2. The curing guide of the light-curing unit was moved on both sides of the specimen for an additional 20 seconds after removing the strips and glass slabs. Ten specimens of each material were prepared and the specimens were measured with a caliper to verify the thickness of the material. The specimens were stored in 37°C distilled water for one day in order to complete polymerization of the materials. No additional procedures were performed during the preparation process. Extreme caution was exercised to prevent the occurrence of voids within the materials; however, when voids did occur, the samples with voids were excluded from the study and new samples were prepared.

Five freshly-extracted intact human molars were used in the current study. Patients were informed that their teeth were to be extracted due to periodontal problems and written informed consent was obtained from every patient whose extracted teeth were used in this *in vitro* study. The teeth were washed and cleaned under running water. The roots were removed 2 mm below the cemento-enamel junction and the remaining tooth portion was embedded in acrylic resin. One-mm thick tooth slices were cut transversally using a slow speed diamond saw (ISOMET Buehler Ltd, Lake Bluff, IL, USA). The slices were kept in tap water until use. A 99% pure aluminum step wedge with seven 1-mm incremental steps was used as an internal radiographic standard and as a gauge to calculate the radiopacity of each material in terms of Al thickness.

Radiographic Procedures

All the specimens were placed directly in the center of 57 x 76 mm Ultra-speed occlusal film (Eastman Kodak Co, Rochester, NY, USA), together with an Al step-wedge and five tooth slices comprised of both dentin and enamel, which were used for comparison (Figure 1). A 2-mm thick lead sheet was placed under the film in order to prevent back-scattered radiation. The film was exposed with a dental x-ray unit (Trophy, Vincennes, France) with 2.5 mm Al equivalent total fil-

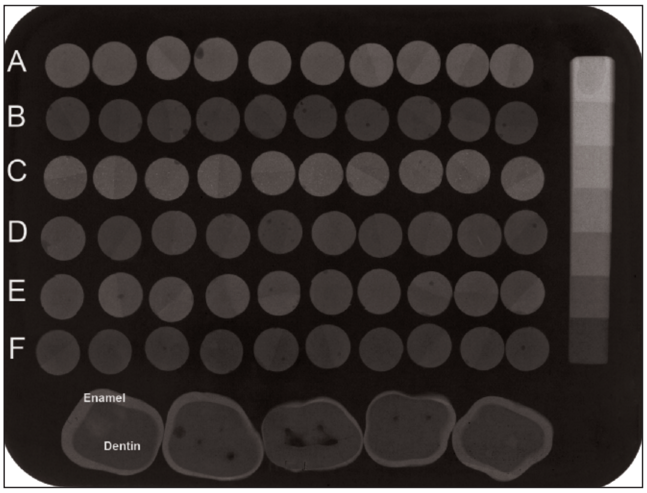

Figure 1: *Sample discs of the flowable resin composites tested and tooth slices used for comparison. (A: Clearfil Majesty Flow, B: Estelite Flow Q, C: Tetric N Flow, D: Esthet X Flow, E: Filtek Supreme XT Flow, F: Gradia Direct LoFlo).*

tration at 70 kV, 10 mA, 0.25 seconds and 40 cm film target-distance. This procedure was repeated in order to obtain two different radiographic sets of the same test specimens.

All the films were processed at once in an automatic processor (Dürr XR 24, Beitigheim, Germany) at 28°C for 4.3 minutes with fresh solutions.

Densitometric Procedures

The radiographs were digitized by a scanner with a transparent adapter (Epson EXP 1680 Pro, Seiko Epson Corp, Nagano, Japan) and saved in TIFF format. On each radiographic image, a 50 x 50 pixel region of interest (ROI) was selected on the center of each test specimen and on each step of the stepwedge. The image was enlarged in order to accurately define the enamel and dentin layers; then, areas to be measured radiographically within the enamel and dentin were selected manually. The mean gray values (MGVs) of base and fog for each test specimen and Al stepwedge were measured by using the histogram function of a computer graphics program (Adobe Photoshop 8.0, Adobe System Inc, San Jose, CA, USA). In this procedure, the MGV of each pixel was represented within a scale ranging between 0 (black) to 255 (white). Then, three measurements were performed and the mean MGVs of the specimens were calculated.

In the first film, MGVs of a selected region (50 x 50 pixels) on the specimen were measured. The same procedure was applied to two other selected regions on the same material and the mean of these three MGVs was accepted as the MGV of that specimen. After calculating the MGV of each step of the aluminum stepwedge, a regression curve equation was defined. Using this equation, the radiopacity of the test materials, in millimeters of equivalent Al, was established. The correlations between the MGVs and aluminum thicknesses were described as $y=-15251x^2 + 29.639x + 65.016$ for the first radiograph. The same procedure was repeated for the second film and the radiopacities of the test materials of this film were determined by using the formula $y=-12047x^2 + 27.461x + 60.934$. Then, all "Al equivalent thickness" values of all test materials were gathered and the mean MGV of each material was calculated.

To investigate the significance of the differences between the groups, data were analyzed with analysis of variance (ANOVA). For pairwise comparisons, the Tukey test was applied. In all tests, α was set as 0.05.

RESULTS

The mean MGVs (net density) and mean radiopacity expressed as Al equivalent millimeters of the test materials are presented in Table 1.

The radiopacity values of Gradia Direct LoFlo, dentin and Estelite Flow Q were close to that of 1 mm Al (1.06, 1.09 and 1.14 mm Al equivalent, respectively). These were the test materials with the lowest MGVs among the samples. On the other hand, Clearfil Majesty Flow and Tetric N Flow were almost two times more radiopaque than 1 mm Al (2.46 and 2.33, respectively). The radiopacity of enamel was equal to that of 1.80 mm Al (Table 1).

Table 1: *The Mean MGVs and Mean Radiopacity Expressed as Al Equivalent Millimeters of the Test Materials*

Material	Mean MGV	Mean Radiopacity*
Clearfil Majesty Flow	123.92 ± 6.30	2.46 ± 0.19[a]
Tetric N Flow	121.19 ± 6.17	2.33 ± 0.15[a]
Enamel	112.96 ± 5.47	1.80 ± 0.33[b]
Filtek SupremeXT Flow	108.40 ± 9.33	1.70 ± 0.14[b]
Esthet X Flow	101.70 ± 5.59	1.49 ± 0.14[c]
Estelite Flow Q	93.23 ± 5.01	1.14 ± 0.10[d]
Dentin	92.23 ± 2.70	1.09 ± 0.11[d]
Gradia Direct LoFlo	91.45 ± 3.55	1.06 ± 0.11[d]
Stepwedge 1	90.23 ± 3.70	1[d+++++++++++]

**in millimeters of equivalent Al.*

Univariate ANOVA analysis of the data revealed statistically significant differences between the test groups ($p<0.001$). Pairwise comparisons were performed with the Tukey's test and four different subgroups were observed: The first group included Gradia Direct

LoFlo, dentin and Estelite Flow Q. The second group included Esthet X Flow. The third group had Filtek Supreme XT Flow and enamel; whereas, the last group contained Tetric N Flow and Clearfil Majesty Flow.

Table 2: *Radiopaque Filler Contents of the Test Materials*

Material	Radiopaque Filler Type**
Clearfil Majesty Flow	silanated barium glass and silanated colloidal silica fillers
Tetric N Flow	ytterbium trifluoride fillers
Filtek SupremeXT Flow	silica nanofillers and zirconia nanofillers
Esthet X Flow	barium fluoro-alumino-boro silicate glass
Estelite Flow Q	silica zirconia and silica titania fillers
Gradia Direct LoFlo	silica fillers

***Obtained from the manufacturers' instructions*

DISCUSSION

In the current study, Gradia Direct LoFlo and Estelite Flow Q demonstrated radiopacity similar to that of dentin, where Tetric N Flow and Clearfil Majesty Flow were found to be more radiopaque than enamel. Filtek Supreme XT Flow had a similar radiopacity to enamel.

The radiopacity of resins has been determined either by observer scores,[9] optic densitometry[1-2,5,10-12] or digital image analysis.[13-14] Attar and others[2] had a similar study protocol to that of the current study, and they have reported that Tetric Flow had the highest radiopacity value of more than 2.5 mm Al, which was above that of enamel. In the current study, Tetric N Flow had a radiopacity of 2.33 mm Al and this finding was in accordance with their results.

It shall be noted that the material characteristics of resin composites depend on their composition and the radiopacity of a resin composite is influenced by the variations provided to enhance the clinical and physical properties of that material. In a previous study, different radiopacity values were obtained for Filtek Flow and Filtek Z250.[2]

The radiopacity values of enamel and dentin observed in the current study were 1.80 mm Al and 1.09 mm Al, respectively. These values were within the range reported in the literature;[16-18] however, it shall be noted that differences between the radiopacity values of the same material in different studies may be attributable to many factors, such as variations within the exposure parameters, especially operating voltage potential of the x-ray units used,[5,14] purity of the Al standard[11,14] and thickness of the test material.[11] Also, the radiopacity of 1 mm dentin was almost equal to that of 1 mm Al in the current study and this was a requisite for any aluminum standard.[10]

As noted, the desirable radiopacity of resin composites is still a controversial issue: some authors recommend that resin composite materials with higher radiopacity than the tooth structure must be preferred in posterior restorations in order to enhance detection of the interface between the restoration and tooth.[1,18-19] On the other hand, radiopaque restorative materials deteriorate both the perception of the details and the visual acuity.[10,20] Therefore, the radiopacity of flowable resin composites becomes more important in deep carious lesions, since they have a tendency to accumulate in deeper cavity angles (resin pools), thus, they may lead to radiographic misdiagnosis.[1] Finally, restorative materials with a moderate degree of radiopacity were favored to those with a higher degree of radiopacity.[20] Among the test materials used in the current study, only Clearfil Majesty Flow and Tetric N Flow had a higher radiopacity than enamel, which is stated by some authors as a required feature of a resin composite,[2-3,18] whereas Filtek Supreme XT Flow revealed similar radiodensity values to enamel.

The radiopacity of resin composites depends on the percentage and type of fillers.[2,22-23] Materials composed of fillers with low atomic numbers, such as silicone, appear radiolucent; whereas materials having fillers with high atomic numbers, such as zirconia, barium glass, barium sulfate and ytterbiumtrifluoride, appear radiopaque.[4,12,22] In the current study, the highest radiopacity values obtained might be attributed to the silanated barium glass fillers of Clearfil Majesty Flow and to the ytterbiumtrifluoride particles of Tetric N Flow. Gradia Direct LoFlo, due to its silica (silicon dioxide) filler content, displayed a radiopacity similar to dentin. Respectively, Estelite Flow Q, Esthet X Flow and Filtek Supreme XT Flow included silica zirconia and silica titania fillers, barium fluoro-alumino-boro silicate glass, and silica and zirconia nanofillers (Table 2). The radiopacity values of these resin materials ranged between dentin and enamel.

Even though ISO stated that a resinous dental material should be at least as radiopaque as the same thickness of pure Al,[7] and the ADA recommended that these materials should present a radiopacity equivalent to 1 mm Al, which is approximately equal to natural tooth dentin,[8] some authors suggested that a radiopacity equal to or slightly greater than enamel is more appropriate to enable secondary caries detection in posterior teeth.[2-3,18] In the current study, Filtek Supreme XT Flow, Tetric N Flow and Clearfil Majesty Flow had similar or higher radiopacity than enamel, and when radiopacity is considered, they appear to be more suitable for posterior dental restorations.

CONCLUSIONS

As revealed in the current study, all six flowable resin composites tested passed the ISO requirements for radiopacity. However, further studies are required to ascertain their potential clinical benefits and limitations, due to differences in the radiopacity of flowable resin composites.

Acknowledgements

The authors thank the companies of Kuraray, Tokuyama Dental, Ivoclar Vivadent, Dentsply DeTrey, 3M ESPE and GC Europe for their generous donation of the materials used in this study.

(Received 13 November 2009; accepted 20 January 2010)

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