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Radiopacity of Flowable Composite by a Digital Technique

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Clinical Relevance

Most of the tested flowable composite materials fulfill the minimal required radiopacity conditions, with slight deviations at different exposure values.

SUMMARY

The aim of this *in vitro* study was to evaluate the radiopacity of 19 current dental flowable composite materials by a digital technique. Digital radiographs were obtained with a CCD sensor using an aluminum step wedge, a 1-mm-thick tooth slice, and a 1-mm-thick flowable composite specimen using five different combinations of exposure and voltage. The radiopacity in pixels was determined using Digora 2.6. software. The equivalent thickness of aluminum for each material was then calculated based on the calibration curve. All of the tested flowable composite materials had higher radiopacities than that of dentin, but in almost every combination of exposure and voltage, there were some composite materials that exhibited radiopacities equal to or slightly greater than enamel $p>\alpha$; $\alpha=0.01$). Of the flowable composite materials tested, 37% showed lower radiopacities than enamel, and 21% of the tested materials had higher radiopacities than the 3-mm aluminum equivalent. The highest radiopacity at all exposure values was produced by the Majesty Flow and Charisma Opal Flow materials, which had radiopacities almost twice that of enamel. Flowable composite materials should have radiopacities greater than that of enamel (ISO 4049), an important consideration for the introduction of new materials to the market. The digital radiopacity analysis techniques used in this study provide an easy, reliable, rapid, and precise method to characterize radiopacity of dental flowable composite materials.

Introduction

The first generation of flowable resin composites was introduced in late 1996. They were created mainly by

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retaining the small particle size of traditional hybrid composites but reducing the filler content and, consequently, the viscosity of the mixture.[1] These materials can be manipulated using a syringe with a loading tip and injected where access using traditional instruments is difficult or impossible because of the low viscosity of these materials.[2] Flowable composite materials are purported to offer higher flow, better adaptation to the internal cavity wall, easier insertion, and greater elasticity than previously available products.[3] They have been recommended for use as liners beneath composite resins because of their low viscosity, increased elasticity, and wettability. These handling characteristics and the syringe delivery system make flowable composite a good choice for sandwich techniques. They are placed at the cementum margins of the proximal box as a liner in Class II resin composite restorations to improve the final marginal integrity, resulting in reduced leakage and postoperative sensitivity.[4–6] Employing an intermediate layer of low-modulus composite can also relieve some of the contraction stress during polymerization. Some *in vitro* studies have shown that the use of flowable composites reduces restoration microleakage and the occurrence of voids and that their use as liners improves the marginal seal of a restoration.[7–9]

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.[10–15] The advantages of radiopaque materials over radiolucent ones include easier detection of recurrent dental caries and easier visualization of the radiographic interface between the materials and tooth substrates.[11]

The International Organization for Standardization (ISO) requires that a resinous dental material be at least as radiopaque as the same thickness of pure Al, and the American Dental Association (ADA) recommends a radiopacity equivalent to 1 mm of Al or 1 mm of dentin.[16,17] The radiopacity of dental materials can be analyzed by a digital technique using x-ray digital sensors and computer software. In the digital imaging technique, the gray scale is inverted relative to the optical density, such that white is assigned a value of 255 (for an eight-bit image) and black is assigned a value of 0. Although flowable composite materials have remained popular and have been widely used for the past 15 years, only a few reports are available on their radiopacity using either digital or analog techniques.[18–22] The main purpose of this study was to evaluate the radiopacity of common flowable composite dental materials at five different exposure times by a digital analysis technique.

MATERIALS AND METHODS

Specimen Preparation

Commercially available and commonly used flowable composite materials were evaluated in this study, as listed in Table 1. Three specimens of each material were prepared according to manufacturer instructions and injected into 1-mm-thick stainless-steel cylinders with an internal diameter of 4.1 mm. After filling each cylinder to capacity, the material's surface was covered with a glass slide, and pressure was applied to force out any excess material. Specimens were light-cured using a light-emitting diode polymerization lamp (Elipar Freelight 2, 3M ESPE, St Paul, MN, USA) with a power of 1000 mW/cm^2 and a wavelength of 430–450 nm for 40 seconds on each side. After removal from the cylinders, the specimens were polished using 400-, 600-, and 1000-grit sandpaper; cleansed with 70% ethyl alcohol; and measured with a digital micrometer to verify that the thickness remained at the critical tolerance of 1.0 ± 0.01 mm. Specimens with macroscopic defects (eg, voids, cracks) were excluded from the study, and new samples were prepared as previously described.

The tooth material for the enamel/dentin specimens was extracted for orthodontic reasons, as approved by the ethics committee of the School of Dental Medicine. A 1-mm enamel/dentin specimen was prepared by longitudinal sectioning of a freshly extracted third 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 step wedge was fabricated by riveting together ten 1-mm-thick plates of aluminum alloy (1100 purity of 99.5% Al). The chemical composition of the aluminum used for fabricating the step wedge was as follows: 0.0014% Cu, 0.0019% Mn, 0.0017% Mg, 0.06% Si, 0.37% Fe, 0.0089% Zn, and 0.025% Ti. The plates were 10 mm wide, and the aluminum wedges ranged from 1- to 10-mm thick.

The Prostyle Intra 50–70 kV digital x-ray machine (Planmeca Oy, Helsinki, Finland) with a DiXi3 B1 digital CCD sensor (Planmeca Oy) was used in this study. Three specimens of each test material, the aluminum step wedge, and a tooth specimen were positioned over the sensor on each of the radiographs

Table 1: *List of Flowable Composite Materials*

Product	Shade	Filler % (wt/vol)	Type (Manufacturer Data)	Manufacturer
Admira Flow	A4	63/50.5	Ormocer-based flowable composite	Voco GmbH, Cuxhaven, Germany
Amaris Flow	HT	NA	Highly esthetic composite-high translucence flowable composite	Voco GmbH, Cuxhaven, Germany
Amaris Flow	HO	NA	Highly esthetic composite-high opaque flowable composite	Voco GmbH, Cuxhaven, Germany
Arabesk Flow	A2	64/NA	Light-curing glass ceramic microhybrid flowable composite with BCS* filler	Voco GmbH, Cuxhaven, Germany
Charisma Opal Flow	A2	62/38	Microparticle hybrid flowable composite	Heraeus Kulzer GmbH, Hanau, Germany
Charisma Flow Baseliner	BS	NA/NA	Microparticle hybrid flowable composite	Heraeus Kulzer GmbH, Hanau, Germany
Filtek Flow	A2	68/47	Flowable composite	3M/Espe, St Paul, MN, USA
Filtek Supreme XT Flow	A3	65/55	Flowable composite	3M/Espe, St Paul, MN, USA
Gradia Direct flo	A3	75/NA	Micro-filled hybrid flowable composite resin	GC Europe NV, Leuven, Belgium
Gradia Direct LoFlo	A3	40/NA	Micro-filled hybrid flowable composite resin	GC Europe NV, Leuven, Belgium
Grandio Flow	A3	80.2/65.7	Nano-hybrid flowable composite	Voco GmbH, Cuxhaven, Germany
Majesty Flow	A3	81/62	Superfilled flowable composite	Kuraray Medical INC, Okayama, Japan
Premise Flow	A3	72.5/54.6	Medium-viscosity flowable composite	Kerr Corporation, Orange, CA, USA
Permaflo	A2	68/NA	Flowable composite	Ultradent, South, South Jordan, USA
Revolution Formula2	A3	51/43	Hybrid flowable composite	Kerr Corporation, Orange, CA, USA
Tetric EvoFlow	A3	62.4/30.7	Nanotechnology flowable composite	Ivoclar Vivadent, Schaan, Liechtenstein
Tetric Econom Flow	A3	64.6/40	Flowable composite	Ivoclar Vivadent, Schaan, Liechtenstein
Tetric Flow	T	NA/NA	Flowable composite	Ivoclar Vivadent, Schaan, Liechtenstein
EsthetX Flow	A3	62/53	Micro hybrid flowable composite	Dentsply DeTrey Gmbh, Konstanz, Germany

(Figure 1). Each specimen was radiographed three times using five different combinations of exposure time and voltage, with a constant source-to-sample distance of 30 cm. These combinations were considered for properly exposed digital images, and they are in accordance with manufacturer instructions. With these combinations of voltage and exposure, we can analyze possible differences in radiopacity between specimens of flowable composite materials. The combinations of voltages and exposures used

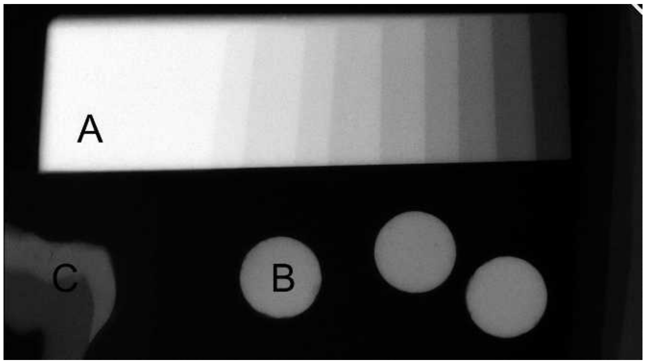

Figure 1. *Digital image obtained from CCD sensor containing tooth structure and tested flowable composite materials. (A): Tooth structure. (B): Tested composite materials. (C): Aluminum step wedge.*

were as follows: (1) 60 kV and 0.06 seconds, (2) 60 kV and 0.08 seconds, (3) 63 kV and 0.06 seconds, (4) 63 kV and 0.08 seconds, and (5) 63 kV and 0.1 seconds.

Digital Imaging

The images, free of any enhancement to contrast or picture quality, were imported into the Dimaxis Pro 4.0 software (Planmeca Oy) and exported in eight-bit TIFF format for subsequent radiopacity analysis (Figure 2). The radiopacity of the specimen, in pixels, was determined using a different type of software, Digora for Windows 2.6 (Soredex, Tuusula, Finland). Digora is Windows-based software capable of measuring density curves of digital radiographs obtained by digital x-ray impregnation on the CCD sensor. The density measurement tool automatically measures the gray shade values in the picture. With the point of the mouse arrow (area 1 pixel × 1 pixel), five different positions were measured in each of the three material specimens. It was important to analyze only those regions that were free of air voids, gaps, cracks, or other similar defects. Using a similar procedure, a tooth slice with enamel and dentin was also measured in five different regions. This procedure was repeated using five different exposures.

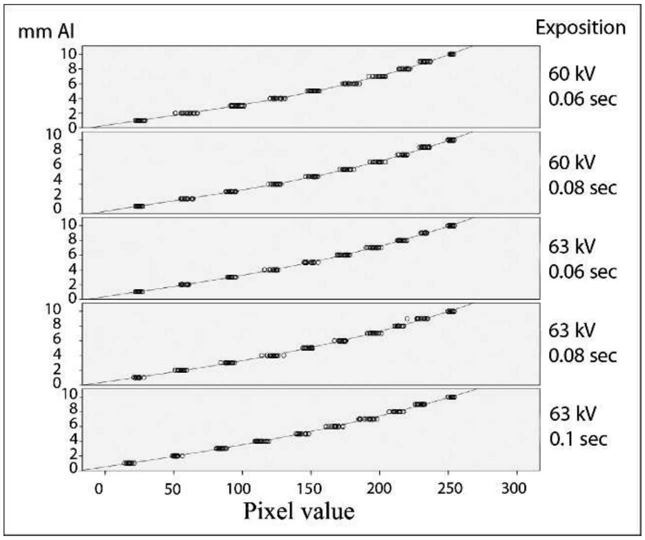

Figure 2. *The curves of pixel values versus mm Al for each exposition.*

The aluminum step wedge (99.5% Al) was used as an internal standard for measuring the comparative equivalent radiopacity of different materials. In 30 random radiographs, each of the 10 steps of the aluminum step wedge was measured for density, and a graph of density versus the thickness of the aluminum alloy at each step was constructed.[23–25] Subsequently, a calibration curve was plotted for selected data using a best-fit logarithmic regression analysis. The equivalent in thickness of aluminum for each material was calculated based on the calibration curve (Figure 2). The measured gray-scale value for each dental material and aluminum corresponded to the extent of attenuation of x-ray transmission through the materials, producing a value converted into absorbance using the following formula:

$$\mathrm{A} = -\log 10(\mathrm{T}) = -\log 10\left(\frac{1-\mathrm{G}}{255}\right),$$

where A is the absorbance, T is the transmittance, and G is the gray-scale value of the material.[26] The same procedure was repeated for five different exposures. Since radiopacity was not a normaly distributed variable, nonparametric tests—Mann-Whitney U-test and Kruskal-Wallis—were used to compare mean values of radiopacity accross different groups and different types of flowable composite materials. The results were statistically analyzed using PASW Statistics 18 software (SPSS Inc, Chicago, IL, USA).

RESULTS

The results of the Kolmogorov-Smirnov test indicated that radiopacity (in mm Al) was not a normally distributed variable ($p<0.05$); therefore, the mean values for the different types of flowable composite materials were compared with the values for dentin and enamel using the Mann-Whitney U-test ($\alpha=0.01$). The equations of the best-fit curves from third-degree polynomial function $f(x) = ax^3 + bx^2 + cx + d$ and their associated errors for all combinations of voltage and exposure are listed in Table 2. The

Table 2: *Regressions and Regressions Errors (Radiopacity/Thickness Correlation)*[a]

Exposition	Regression Parameters (SE)				R^2	Mean Residuals
	a	b	c	d		
60 kV 0.06 s	0.332 (0.059)	0.028 (0.002)	−2.36E-05 (0.000)	2.59E-07 (0.000)	0.998	0.018
60 kV 0.08 s	0.310 (0.045)	0.029 (0.001)	−2.96E-05 (0.000)	2.62E-07 (0.000)	0.999	0.011
63 kV 0.06 s	0.362 (0.044)	0.027 (0.001)	−1.231E-06 (0.000)	1.787E-07 (0.000)	0.999	0.011
63 kV 0.08 s	0.418 (0.056)	0.026 (0.002)	8.753E-06 (0.000)	1.537E-07 (0.000)	0.998	0.018
63 kV 0.1 s	0.522 (0.043)	0.028 (0.001)	1.382E-05 (0.000)	1.050E-07 (0.000)	0.998	0.015

[a] *a, b, c, d = coefficients of third-degree polynomial function.*

calibration curve for aluminum thickness versus pixel value was plotted using the best-fit logarithmic regression method. The third-degree polynomial is a mathematical curve that best represents the given data, as shown in Figure 2 for each combination of voltage and exposure. The absorbance of the aluminum step wedge at different combinations of exposure and voltage is reported in Table 3. The radiopacities of flowable composite materials at different exposures are presented in Table 4.

All of the tested flowable composite materials had higher radiopacities than dentin *($p<0.001$)*, but at almost every combination of exposure and voltage, there were some composite materials with radiopacities equal to or slightly greater than enamel ($p>0.01$). Filtek Flow, Grandio Flow, Amaris Flow HO, and Amaris Flow HT showed no statistically significant differences in radiopacity as compared with enamel ($p>0.01$), at an exposure value of 60 kV and 0.06 seconds. The highest radiopacities for all exposure values were produced by the Majesty Flow and Charisma Opal Flow materials, with almost twice the radiopacity of enamel.

DISCUSSION

In this study, the radiopacities of all 19 tested materials were higher than that for dentin, and 12 of the flowable composite materials produced higher radiopacities than enamel. According to the ISO standards, the minimum radiopacity requirement for these materials is equivalent to 1 mm of aluminum alloy 1100.[16] The radiopacity values of tooth samples observed in this study were equivalent to 2.02–2.08 mm of Al for enamel and 1.09–1.13 mm of Al for dentin, according to the different exposure values. It should be noted that differences in radiopacity values for the same material from different studies may be a result of many factors, such as variations in exposure parameters, purity of the Al standard, thickness of the test materials, and differences between analog and digital assay techniques.[24–28] The purity of the aluminum step wedge is very important because 4% copper in an aluminum alloy would result in radiopacity measurements a full 50% lower than those of 99.5% aluminum, creating a systematic error of 1.25%.[29] Therefore, an aluminum step wedge of 99.5% purity was used in this study, containing no more than 0.37% iron or 0.0014% copper.

Digital radiology does not involve film development, a process that introduces variation in the final radiograph.[16,30,31] Digital image analysis is considered to have the same accuracy as transmission densitometry and can produce measurements equivalent to those obtained with film with reduced noise, providing precise and trustworthy numerical values for comparative radiodensity studies.[19,22,31–34] Transmission densitometry measures optical density, a logarithmic measure of the ratio of transmitted to incident light through the film image. In digital image analysis, we measure radiographic density directly using the gray scale of the pixels, measuring the values on a scale of 0 to 255 using the computer software.[26,31] Furthermore, it is not necessary to perform any subtraction (as with conventional x-ray film) when calculating the radiopacity.[22]

The application of a flowable composite between the adhesive and the conventional composite to create an elastic intermediate layer has been proposed.[34–37] The elasticity of this layer may absorb

Table 3: *Absorbance Values for Aluminum Step Wedge*

		60 kV 0.06 s		60 kV 0.08 s		63 kV 0.06 s		63 kV 0.08 s		63 kV 0.1 s	
Aluminum, mm		**Pix**	**Abs**	**Pix**	**Abs**	**Pix**	**Abs**	**Pix**	**Abs**	**Pix**	**Abs**
A1	Mean value	24.90	0.04	24.30	0.04	24.10	0.04	23.60	0.04	17.65	0.03
	SD	1.98	0.00	1.52	0.00	1.33	0.00	1.76	0.00	1.72	0.00
A2	Mean value	59.9	0.12	58.90	0.11	57.60	0.11	55.30	0.11	51.40	0.09
	SD	4.59	0.01	2.79	0.01	2.11	0.01	2.39	0.01	1.54	0.00
A3	Mean value	95.75	0.21	92.00	0.19	91.45	0.19	89.65	0.19	84.15	0.17
	SD	3.19	0.01	2.41	0.01	1.67	0.00	2.43	0.01	2.06	0.01
A4	Mean value	125.20	0.29	124.40	0.29	122.30	0.28	121.90	0.28	112.90	0.25
	SD	3.44	0.01	2.30	0.01	2.98	0.01	3.42	0.01	2.86	0.01
A5	Mean value	152.35	0.39	151.45	0.39	149.75	0.38	148.10	0.38	142.80	0.36
	SD	2.49	0.01	2.39	0.01	3.13	0.01	2.40	0.01	3.02	0.01
A6	Mean value	178.65	0.52	175.85	0.51	173.70	0.50	172.65	0.49	167.80	0.47
	SD	3.68	0.02	2.64	0.01	3.03	0.02	2.23	0.01	3.55	0.02
A7	Mean value	199.70	0.67	198.65	0.66	196.30	0.64	195.55	0.63	191.00	0.60
	SD	3.33	0.03	2.43	0.02	2.98	0.02	2.96	0.02	4.28	0.03
A8	Mean value	218.35	0.84	217.20	0.83	215.15	0.81	213.90	0.79	212.65	0.78
	SD	2.52	0.03	2.09	0.02	1.93	0.02	1.74	0.02	2.82	0.03
A9	Mean value	232.65	1.06	233.20	1.07	232.65	1.06	229.60	1.01	229.60	1.00
	SD	2.39	0.05	2.29	0.05	1.23	0.02	3.49	0.06	2.26	0.04
A10	Mean value	252.40	2.01	251.85	1.97	252.35	2.06	252.00	2.00	252.60	2.07
	SD	0.68	0.13	1.49	0.26	1.49	0.28	1.56	0.27	1.23	0.24

Abbrevations: Abs, absorbance; Pix, pixels.

the contraction stress generated by the conventional composite, reducing tooth/restoration interfacial stress[34] and cuspal deflection occurring during polymerization shrinkage.[38] The flowable composite liner recommended for deep class II cavities may act as a flexible intermediate layer, relieving stresses during polymerization shrinkage of the restorative resin.[39–41] It can be concluded that usage of flowable

Table 4: *Radiopacity of Flowable Composite Materials at Different Exposures*

Composite Materials/Radiopacity Al (SD)	**60 kV 0.06 s**	**60 kV 0.08 s**	**63 kV 0.06 s**	**63 kV 0.08 s**	**63 kV 0.1 s**
Majesty Flow A3	3.91 (0.11)	3.91 (0.11)	3.94 (0.17)	4.02 (0.21)	3.91 (0.15)
Charisma Opal Flow A2	3.81 (0.12)	3.8 (0.15)	3.88 (0.12)	3.81 (0.12)	3.84 (0.17)
Tetric EvoFlow A3	3.23 (0.1)	3.2 (0.07)	3.27 (0.11)	3.05 (0.09)	3.3 (0.15)
Tetric Flow T	3.13 (0.13)	3.1 (0.16)	3.12 (0.11)	3.09 (0.1)	3.22 (0.19)
Premise Flow A3	2.91 (0.07)	2.86 (0.11)	2.94 (0.16)	2.95 (0.12)	2.87 (0.2)
Permaflo A2	2.88 (0.1)	2.89 (0.14)	3.12 (0.14)	3.01 (0.17)	3.13 (0.14)
Esthet X Flow A3	2.35 (0.1)	2.35 (0.1)	2.44 (0.1)	2.31 (0.09)	2.36 (0.1)
Charisma Flow BS	2.25 (0.09)	2.25 (0.12)	2.28 (0.1)	2.3 (0.12)	2.22 (0.08)
Gradia Direct flo A3	2.24 (0.11)	2.19 (0.09)	2.12 (0.09)	2.19 (0.07)	2.11 (0.11)[d]
Filtek Supreme XT Flow A3	2.2 (0.13)	2.34 (0.09)	2.2 (0.14)	2.28 (0.12)	1.98 (0.09)d
Filtek Flow A2	2.15 (0.1)[a]	2.12 (0.08)	2.05 (0.11)[c]	2.07 (0.11)[d]	2.14 (0.09)[d]
Grandio Flow A3	2.13 (0.06)[a]	2.14 (0.09)	2.11 (0.11)[c]	2.11 (0.12)[d]	2.19 (0.11)
Enamel	2.07 (0.05)	2.02 (0.08)	2.03 (0.1)	2.04 (0.09)	2.08 (0.1)
Amaris Flow HO	2.05 (0.1)[a]	1.86 (0.07)	1.96 (0.08)[c]	1.92 (0.09)	1.98 (0.12)[d]
Amaris Flow HT	2.02 (0.07)[a]	1.95 (0.06)[b]	1.97 (0.09)[c]	2 (0.07)[d]	2.05 (0.07)[d]
Arabesk Flow A2	1.87 (0.08)	1.83 (0.08)	1.81 (0.11)	1.8 (0.1)	1.87 (0.07)
Tetric Econom Flow A3	1.87 (0.07)	1.83 (0.08)	1.86 (0.1)	1.85 (0.07)	1.92 (0.08)
Admira Flow A4	1.85 (0.09)	1.84 (0.07)	1.87 (0.11)	1.89 (0.12)	1.91 (0.1)
Revolution Formula2 A3	1.58 (0.08)	1.55 (0.08)	1.58 (0.08)	1.59 (0.08)	1.46 (0.1)
Gradia Direct LoFlo A3	1.56 (0.06)	1.49 (0.06)	1.53 (0.09)	1.42 (0.12)	1.41 (0.1)
Dentin	1.12 (0.08)	1.1 (0.06)	1.09 (0.08)	1.11 (0.08)	1.13 (0.08)

[a,b,c,d] *Same letters show no statistical significance in comparison with enamel ($p>0.01$).*

composite materials as a liner below the packable composite materials is recommended.[4,41–45]

Some authors have suggested that composite materials with higher radiopacities than that of the tooth structure should be used for posterior restorations to enhance detection of the interface between the restoration and the tooth.[19,21,46] Materials with greater radiopacities, higher than that of enamel, were favorable for a true-negative diagnosis.[47] The observed radiopacity for some flowable composite resin materials in this study was lower than is desirable for use under posterior restorations; therefore, they are not recommended as liners. Radiopacity equal to or slightly greater than that of enamel is preferable to facilitate detection of secondary caries and marginal defects in posterior teeth.[7,18–22,28,48] If the initial increment of a posterior restoration has a radiopacity equal to or slightly greater than that of dentin, it may not be possible to detect the extent of the restoration, a small defect, or an overhang.[21] In contrast, some authors have suggested that highly radiopaque restorative materials deteriorate visual acuity and complicate the perception of details such as caries, lesions, and marginal defects, suggesting that moderate radiopacity might be favorable for easier caries detection.[11,15,29] All of the tested flowable materials showed significant differences in radiopacity as compared with dentin, but not all differed significantly from enamel. Introduction of chemical elements with high atomic numbers, such as zinc, strontium, zirconium, barium, and lanthanum, produce more radiopaque materials.[7,12–14] Tetric composite materials contain yttrium (Y, atomic number = 39) and ytterbium (Yb, atomic number = 70), which can contribute a high level of radiopacity, probably the source of high radiopacity in the Tetric Flow group of materials.[19] Further, barium (Ba, atomic number = 56) is the element most commonly incorporated into composite restorative materials to increase their radiopacities. The flowable composites with the highest radiopacities were Majesty Flow and Charisma Opal Flow, with almost four times the radiopacity of dentin and twice that of enamel. According to manufacturer data, Majesty Flow has very high filler loading, similar to that of many universal composite resins, possibly explaining its high radiopacity. The manufacturer of the Charisma Opal composite materials claims that its filler consists of x-ray opaque microglass and silicon dioxide, both of which increase radiopacity. Ergücü and others[18] reported that Clearfil Majesty Flow and Tetric Flow had the highest radiopacities among six tested flowable composite materials observed and that the lowest radiopacity observed in their study was produced by the Gradia Direct LoFlo material. The highest radiopacity values obtained in that study may be attributed to silanated barium glass fillers in the Clearfil Majesty Flow and ytterbium trifluoride particles in Tetric Flow. The lowest observed radiopacity, produced by Gradia Direct LoFlo, may be attributed to its silicon dioxide filler content, which has a radiopacity value similar to that of dentin.[18] Moreover, the Gradia Direct LoFlo material also produced the lowest radiopacity in our study. The Tetric Flow material, as observed in other studies, showed the highest radiopacity, almost twice that of enamel.[19,21] The Tetric Flow material also produced the highest radiopacity (twice that of enamel) among flowable materials when measured using film radiographs and phosphor storage plates (Digora).[22] However, the radiopacity of the Tetric Econom Flow material was lower than the value for enamel in all exposure combinations. This could result from the fact that Tetric Econom Flow is an economy product system as opposed to premium composite systems from the Tetric Group, such as Tetric Flow and Tetric Evo Flow, which have greater amounts of radiopaque elements in their compositions. It is important to note that results from different studies may vary as a result of different techniques and materials used (eg, digital or analog, composition of aluminum step wedge, material thickness, etc). There may also be substantial variation in the composition and content of a filler from what is claimed by the manufacturer; thus, a detailed chemical analysis of each composite material is needed to determine its exact composition.

CONCLUSION

Most of the flowable composite materials tested produced radiopacities similar to or greater than enamel, with slight deviations at different exposure values. The Majesty Flow, Charisma Flow, and Tetric Flow materials showed the highest radiopacities at all exposure values. The digital techniques used for measurement of radiopacity in this study provided an easy, reliable, rapid, and precise approach to evaluate the different dental flowable composite materials.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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