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ORIGINAL RESEARCH

Radiopacity of 28 Composite Resins for Teeth Restorations

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ABSTRACT

Aim: Radiopacity is a fundamental requisite to check marginal adaptation of restorations. Our objective was to assess the radiopacity of 28 brands of light-cured composite resins and compare their radiopacity with that of enamel, dentin, and aluminum of equivalent thickness.

Materials and methods: Composite resin disks (0.2, 0.5, and 1 mm) were radiographed by the digital method, together with an aluminum penetrometer and a human tooth equivalent tooth section. The degree of radiopacity of each image was quantified using digital image processing. Wilcoxon nonparametric test was used for comparison of the mean thickness of each material.

Results: All of the materials tested had an equal or greater radiopacity than that of aluminum of equivalent thickness. Similar results for enamel were found with the exception of Durafill, which was less radiopaque than enamel ($p < 0.05$). All the specimens were more radiopaque than dentin, except for P90 (which was equally radiopaque) and Durafill (which was less radiopaque). The thickness of the specimens may influence the similarity to the enamel's radiopacity. All of the composite resins comply with specification #27 of the American Dental Association. The radiopacity of Amelogen Plus, Aph, Brilhiante, Charisma, Concept Advanced, Evolux X, Exthet X, Inten S, Llis, Master Fill, Natural Look, Opallis, P60, Tetric, Tph, Z100, and Z250 was significantly higher than that of enamel ($p < 0.05$).

Conclusion: With these composites, it is possible to observe the boundaries between restoration and tooth structure, thus allowing clinicians to establish the presence of microleakage or restoration gap.

Clinical significance: Suitable radiopacity is an essential requisite for good-quality esthetic restorative materials. We demonstrate that only some composites have the sufficient radiopacity to observe the boundaries between restoration and tooth structure, which is the main cause of restoration failure.

Keywords: Composite resins, Digital radiography, Image processing.

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INTRODUCTION

The development of dentinal adhesive systems has made the use of composite resins in both anterior and posterior teeth routine in clinical practice. The radiopacity of restorative materials is an essential requisite for assessing restoration overcontouring, marginal adaptation defects, such as overhangs and gaps, caries relapse, excessive proximity to the pulp, and the lack of a contact point, among other unfavorable conditions, thus contributing to radiographic diagnosis.[1,2]

To date, no consensus has been reached on the ideal degree of radiopacity of esthetic restorative materials. However, measurement of radiopacity has been standardized by two sets of guidelines. Specification #27 of the American Dental Association (ADA)[3] states that a composite resin should have the radiopacity equivalent to 1-mm-thick sample of aluminum, which is approximately equal to natural tooth dentin. Requirements established by the Organization for Standards (ISO/DP 4049)[4] specify that the radiopacity of a 2-mm-thick specimen of the material should be equal to that of a 2 mm or larger thickness of aluminum.

One of the techniques used to evaluate the radiopacity of dental materials is to compare a specific thickness of a composite with an aluminum step wedge of known thickness under controlled radiographic conditions. The radiopacity of a dental material specimen is usually expressed in terms of equivalent aluminum thickness (millimeters) using a reference calibration curve. The radiopacity of composite resins has been studied extensively, but most research has used test specimens of 1, 2 mm or even greater thickness,[2,5-8] which are potentially too thick to indicate the radiopacity of less thick restoration areas that are often observed in clinical practice.

There are several types and brands of composite resins on the market with various degrees of radiopacity. This variation has been a major complaint among dentists because it may lead them to mistake presumed microleakages for the restorative material itself.

The aim of the present study is to assess the radiopacity of 28 brands of light-cured composite resins for direct use, available on the market, using a digital imaging method and to compare their radiopacity with that of enamel, dentin, and aluminum of equivalent thickness.

MATERIALS AND METHODS

Composite Resin Specimens

A set of 28 brands of light-cured composite resins was studied (Table 1). Three disks of each of three different thicknesses (0.2, 0.5, and 1 mm) were manufactured, totaling nine disks of each material. These different thicknesses were used to simulate the various clinical possibilities encountered by dentists. The composite resin disks were made using three different thickness acetate matrices, which were perforated by a wheel-mounted diamond bur, through which the resin was inserted (Fig. 1). The resin was then pressed using a polyester strip.

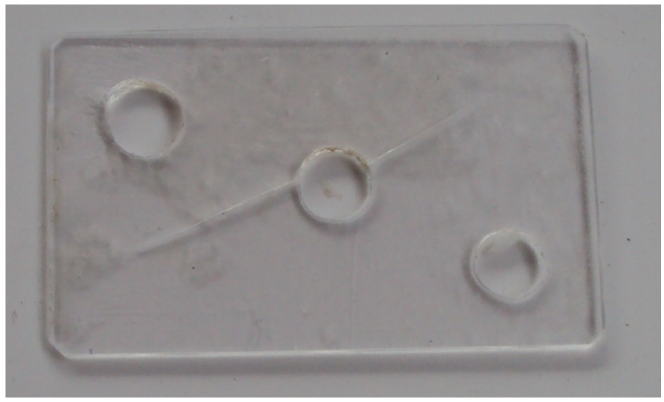

Fig. 1: Acetate matrix with perforations for inserting the material

The disks were light-cured according to the manufacturers' recommendations using an Ultra light-emitting diode light-curing unit and finished with medium-, fine-, and extra-fine-grit Sof Lex disks (3M ESPE, St Paul,

Table 1: Composite resins analyzed in the study

Brand	*Manufacturer*	*Country of origin*	*Indication*	*Shade*
Amaris	Voco	Germany	Anterior/posterior	A2
Amelogen Plus	Ultradent	USA	Anterior/posterior	A2
Aph	Dentsply	USA	Posterior	A2
Brilhiante	Vigodent	Brazil	Anterior/posterior	A2
Charisma	Heraeus—Kulzer	Germany	Anterior/posterior	A2
Concept Advanced	Vigodent	Brazil	Anterior/posterior	A2
Durafill	Heraeus—Kulzer	Germany	Anterior	A2
Evolux X	Dentsply	USA	Anterior/posterior	A2
Exthet X	Dentsply	USA	Anterior/posterior	A2
Glacier	SDI	Australia	Anterior/posterior	A2
Grandio	Voco	Germany	Anterior/posterior	A2
Ice	SDI	Australia	Anterior/posterior	A2
Inten S	Ivoclair-Vivadent	Germany	Anterior/posterior	A2
Llis	FGM	Brazil	Anterior/posterior	A2
Master Fill	Biodinâmica	Brazil	Anterior/posterior	A2
Natural Look	DFL	Brazil	Anterior/posterior	A2
Opallis	FGM	Brazil	Anterior/posterior	A2
P60	3M ESPE	USA	Posterior	A2
P90	3M ESPE	USA	Posterior	A2
Rock	SDI	Australia	Posterior	A2
Supreme	3M ESPE	USA	Anterior/posterior	A2
Tetric	Ivoclair-Vivadent	Germany	Anterior/posterior	A2
Tph	Dentsply	USA	Anterior/posterior	A2
Venus	Heraeus—Kulzer	Germany	Anterior/posterior	A2
Vit L Escence	Ultradent	USA	Anterior/posterior	A2
Z100	3M ESPE	USA	Anterior/posterior	A2
Z250	3M ESPE	USA	Anterior/posterior	A2
Z350	3M ESPE	USA	Anterior/posterior	A2

Minnesota, USA). Thickness was verified with a digital pachymeter.

Teeth Specimens

The three different thicknesses were also simulated on two teeth specimens, which were donated by the University Tooth Bank. These teeth were used as a radiopacity reference for enamel and dentin for comparison with the composite resin specimens. They were first stored in water and then embedded in acrylic resin, positioned and cut into 0.5 and 1-mm-thick pieces (premolar and canine) using a precision cutting machine (IsoMet 1000; Buehler, Lake Bluff, IL, USA). Finishing was done with an automatic grinding and polishing machine (Ecomet-3; Buehler, IL, USA). A 0.2-mm-thick tooth section was obtained by grinding one of the 0.5 mm sections with a micromotor and sandpaper disk. After grinding, the size was verified with a digital pachymeter (Fig. 2).

Digital Analysis of Radiopacity

The resin disks were placed on a horizontal table over a size-2 phosphor plate sensor (New Digora Optime Soredex 2009, Tuusula, Finland), in groups of 3 by 3 and side by side (grouped by the same brand and same thickness). Each group was imaged together with a tooth section prepared at the same thickness for radiopacity assessment. An aluminum penetrometer containing six steps, the first measuring 0.2 mm, the second 0.5 mm, and the others increasing 0.5 mm at each step, was also used in all the assessments (Fig. 3). All steps were also verified with a digital pachymeter.

The X-ray apparatus (Intrex VSK; Keystone, Burlington, USA) was set to operate at 70 kVp, 10 mA, and an exposure time of 0.2 seconds. A focal distance of 30 cm was standardized using a film holder. This film holder was only used to standardize the correct distance of the X-ray cone, as is commonly used for obtaining periapical radiographs using the paralleling technique.

Processing was performed with a scanner (New Digora Optime; Soredex 2009, Tuusula, Finland) coupled to a personal computer (Hewlett-Packard, Palo Alto, USA). The images were saved in DICOM format and then imported into a dental imaging program (Kodak, Atlanta, USA) to perform the radiopacity readings. The readings were made based on pixel intensity, with values ranging from 0 to 255, where 0 represented black (completely radiolucent) and 255 represented white (completely radiopaque).

A dental imaging program (Kodak, Atlanta, USA) was used to draw 8-mm lines through the central regions on the enamel and dentin layers, the central portion of the step corresponding to the aluminum scale, and the central portion of each composite resin disk. Radiopacity readings were made on three equidistant points along a line (Fig. 4). The arithmetic mean of the three readings obtained for each material was considered its final radiopacity value.

Data were tabulated using Microsoft Excel, Wilcoxon nonparametric test was used for the comparisons, and a 5% significance level was used. A statistically significant radiopacity difference between the materials tested and also between the comparisons performed with the different reference materials was recorded when the p value was smaller than 0.05 ($p < 0.05$).

This study was submitted to and approved by the research ethics committee of the institution where the research was conducted.

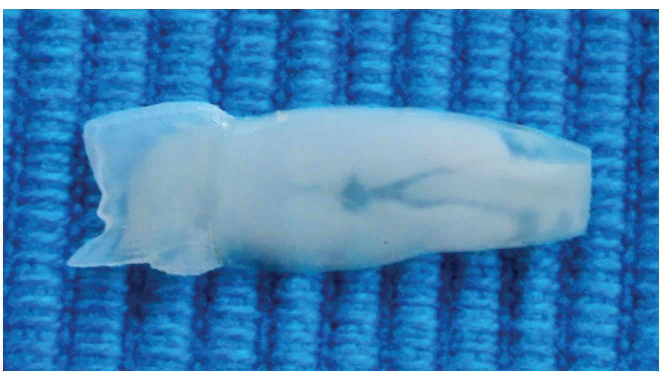

Fig. 2: Finished tooth section used in the study

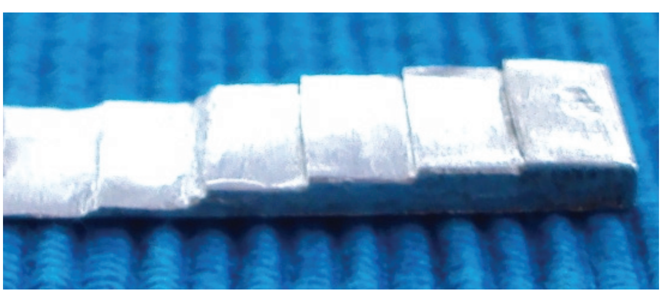

Fig. 3: Profile view of the aluminum penetrometer

Fig. 4: Kodak dental imaging software used for the radiopacity readings

RESULTS

The mean results obtained for the test specimens were compared with those of each of the reference materials: enamel, dentin, and aluminum. Three thicknesses were considered for comparison. Therefore, each composite resin brand had a sample size of nine measurements (three repetitions in three thicknesses, 0.2, 0.5, and 1 mm). For statistical analysis, the mean of these three thicknesses for each material was considered (Table 2).

Comparing the Test Specimen Results to Those of the Three Reference Materials: Enamel, Dentin, and Aluminum

Test Specimen vs Enamel

There was no difference between the results obtained for enamel and those obtained for the test specimens for the following composite resins: Amaris, Glacier, Grandio, Ice, P90, Rock, Supreme, Venus, Vit Escence, and Z350 ($p > 0.05$).

The radiopacity of Amelogen Plus, Aph, Brilhiante, Charisma, Concept Advanced, Evolux X, Exthet X, Inten S, Llis, Master Fill, Natural Look, Opallis, P60, Tetric, Tph, Z100, and Z250 was higher than that of enamel ($p < 0.05$).

The radiopacity of Durafill was lower than that of enamel ($p < 0.05$) (Table 2).

Test Specimens vs Dentin

There was no difference between dentin and P90 ($p > 0.05$).

The radiopacity of Amaris, Amelogen Plus, Aph, Brilhiante, Charisma, Concept Advanced, Evolux X, Exthet X, Glacier, Grandio, Ice, Inten S, Llis, Master Fill, Natural Look, Opallis, P60, Rock, Supreme, Tetric, Tph, Venus, Vit Escence, Z100, Z250, and Z350 was higher than that of dentin ($p < 0.05$).

The radiopacity of Durafill was lower than that of dentin ($p < 0.05$) (Table 2).

Test Specimen vs Aluminum

The only composite resin that did not present a statistically significant difference ($p > 0.05$) was Durafill, which proved to have a radiopacity similar to aluminum. The radiopacity of all other brands was higher than that of aluminum ($p < 0.05$) (Table 2).

Table 2: Mean radiopacity value of the composite resin test specimens compared with those of enamel, dentin, and aluminum

	Test specimen		*Enamel*		*Dentin*		*Aluminum*	
Composite resin	*Mean*	*Standard deviation*	*Mean*	*p-value*	*Mean*	*p-value*	*Mean*	*p-value*
Amaris	137.3	29.1	138.7	0.813	111.7	0.001	102.1	0.008
Amelogen Plus	170.3	38.8	141.8	0.028	107.6	0.008	104.6	0.008
Aph	168.7	44.4	132.9	0.008	112.7	0.008	106.0	0.008
Brilhiante	162.6	40.8	128.6	0.008	106.2	0.008	105.0	0.008
Charisma	155.4	34.5	130.1	0.008	111.8	0.008	98.4	0.008
Concept Advanced	158.9	37.0	140.1	0.011	117.1	0.008	104.8	0.008
Durafill	95.6	11.1	144.3	0.008	121.4	0.008	105.3	0.066
Evolux X	174.9	42.8	131.4	0.008	111.4	0.008	105.7	0.008
Exthet X	168.1	41.1	138.0	0.008	113.4	0.008	108.3	0.008
Glacier	137.0	21.2	129.0	0.110	109.1	0.008	106.6	0.008
Grandio	140.6	24.4	141.0	0.953	115.7	0.008	105.9	0.008
Ice	125.7	19.9	129.8	0.515	109.3	0.008	104.2	0.008
Inten S	172.9	40.7	135.9	0.008	112.2	0.008	97.8	0.008
Llis	160.2	41.9	128.4	0.011	109.2	0.008	109.0	0.008
Master Fill	150.1	33.3	140.3	0.036	115.3	0.008	101.7	0.008
Natural Look	169.2	43.3	121.9	0.008	104.6	0.008	102.7	0.008
Opallis	150.3	29.6	135.4	0.028	114.6	0.008	112.6	0.011
P60	145.9	33.7	131.9	0.021	112.3	0.008	102.3	0.011
P90	119.3	14.4	137.4	0.139	117.8	0.594	106.8	0.021
Rock	125.3	19.2	126.3	0.953	107.4	0.011	106.4	0.011
Supreme	135.6	30.8	136.4	>0.999	115.0	0.008	104.0	0.012
Tetric	175.7	44.4	130.0	0.008	110.2	0.008	99.4	0.008
Tph	172.5	44.2	133.7	0.008	112.8	0.008	104.2	0.008
Venus	150.9	32.6	142.6	0.401	118.8	0.015	101.3	0.008
Vit L Escence	128.3	22.5	121.8	0.400	105.6	0.011	107.9	0.011
Z100	156.4	32.1	135.6	0.011	115.0	0.008	108.0	0.011
Z250	149.3	28.1	135.1	0.015	111.7	0.008	107.1	0.008
Z350	141.1	26.8	136.2	0.514	112.9	0.011	107.7	0.011

Table 3: Comparison between the radiopacity levels of the studied composite resins and those of the reference materials, according to the thicknesses of 0.2, 0.5, and 1 mm

	Material/thickness (mm)											
Composite resin	*E*	*D*	*A*	*T*	*E*	*D*	*A*	*T*	*E*	*D*	*A*	*T*
	0.2	*0.2*	*0.2*	*0.2*	*0.5*	*0.5*	*0.5*	*0.5*	*1*	*1*	*1*	*1*
Amaris	103	98	85	109	144	118	97	132	169	119	124	172
Amelogen Plus	130	92	96	127	119	107	103	172	176	123	115	212
Aph	102	97	99	121	123	107	105	165	174	134	114	220
Brilhiante	99	95	87	118	140	109	108	160	146	114	120	210
Charisma	97	94	90	119	120	107	97	154	173	135	108	193
Concept Advanced	100	95	94	118	144	118	109	158	176	138	112	200
Durafill	132	116	92	96	123	109	105	94	178	139	118	97
Evolux X	102	94	95	128	122	106	108	175	170	135	114	222
Exthet X	101	93	104	123	147	115	102	167	166	132	119	214
Glacier	105	96	95	121	118	108	105	128	164	123	119	162
Grandio	109	102	100	116	142	110	108	139	172	135	110	167
Ice	103	98	95	111	121	105	100	118	166	126	118	148
Inten S	101	96	97	130	139	108	84	170	168	132	112	219
Llis	99	92	93	114	120	104	107	159	166	131	127	208
Master Fill	105	100	86	115	144	113	106	149	172	133	113	186
Natural Look	100	90	91	120	124	111	101	172	142	112	116	216
Opallis	105	94	104	118	124	114	108	149	178	136	125	183
P60	99	91	93	108	123	109	100	147	174	137	114	182
P90	103	96	100	106	128	116	105	120	181	141	116	132
Rock	99	93	99	108	115	101	106	121	165	129	115	147
Supreme	103	94	95	104	125	107	105	130	181	143	112	172
Tetric	98	89	89	128	122	108	99	174	170	133	110	226
Tph	107	95	97	125	124	108	103	169	171	135	113	223
Venus	132	116	87	119	127	112	98	147	168	129	119	187
Vit L Escence	102	97	97	111	125	111	108	124	138	109	118	150
Z100	101	92	105	126	124	108	106	150	181	144	113	193
Z250	102	91	95	123	129	111	105	145	175	133	121	180
Z350	103	96	98	113	122	104	109	145	183	139	115	165

E: Enamel; D: Dentin; A: Aluminum; T: Test specimen; Values in pixels

Comparing All Brands to the Reference Materials, Considering All Thicknesses

We quantitatively compared the results obtained for each material (enamel, dentin, and aluminum) with those obtained for the test specimens of different thicknesses (Table 3).

The 0.2-mm test specimen results closest to those of enamel were those obtained for Amaris, Amelogen Plus, and Supreme. The radiopacity of Durafill and Venus was lower than that of enamel and that of dentin. All resins had a radiopacity similar to or higher than that of aluminum.

The 0.5-mm test specimen results closest to those of enamel were those obtained for Amaris, Ice, Rock Supreme, and VIT Escence. Durafill was the only composite resin that showed a radiopacity level lower than that of enamel, lower than that of dentin, and lower than that of aluminum.

The 1-mm test specimen results closest to those of enamel were those obtained for Amaris, Glacier, Grandio, Opalis, P60, and Z250. The radiopacity of Durafill was lower than that of enamel, lower than that of dentin, and lower than that of aluminum.

DISCUSSION

Light-cured composite resins were introduced to replace amalgam for restoring posterior teeth. They present different levels of radiopacity, as demonstrated in our study. When placing a restoration, it is essential to be able to distinguish the tooth, the restoration, and the carious lesion to avoid false diagnoses.[1,2,9,10]

Opinions vary greatly in the related literature as to the level of radiopacity that composite resins should have. Some authors only stress that the material must be radiopaque,[11] whereas others state that the material radiopacity level should be equal to or greater than that of dentin, which is the acceptable inferior limit of radiopacity.[1,2] Most authors, however, agree that the radiopacity level of the material should be equal to or greater than that of enamel.[7,9,10,12-15] We agree with this last definition because it is difficult to detect secondary caries, to check the contour, and to check for complete filling of the cavity accurately when the radiopacity of the restorative material is similar to, or lower than, that of dentin. This difficulty still exists when the radiopacity level of the material is lower than, or equal to, that of enamel, but is restricted to the areas where the restoration is in contact with the tooth structure. We may thus conclude that the clinically ideal radiopacity for a restorative material would be higher than that of enamel.[16] Even though the superior limit has not been established, some authors argue that very radiopaque materials, such as amalgam, impair radiographic identification of marginal adaptation, recurrent caries, and other defects.[17]

The related literature presents many methods for investigating the degree of radiopacity of materials. The procedure of comparing the radiopacity level of one given material to that of another—that serves as a reference—is common to all methods. Aluminum is considered the choice reference material by some authors.[11,12,18] Tooth sections with thicknesses equivalent to those of the material under investigation are used in other works.[2,5,13,19] Still other investigators combined both types; they compared samples of the studied material with aluminum and with tooth sections,[1,6,7,20-26] as in our experiment. Using this method, we observed that dentin does not always have the same radiopacity as its aluminum equivalent (Table 3). Therefore, in our opinion, the conversion of the optical density (or pixel values) of samples to equivalent millimeters of aluminum (mm Al) should be used with caution as it may produce approximate but not exact values compared with that of dentin.

Another important detail that should be considered is the test specimen thickness. Different thicknesses are found in the related literature: 3 mm,[2,6,23] 2.5 mm,[9,13,15,21] 2 mm,[5-7,20,23] and 1 mm.[6,8,23] Our study used test specimen thicknesses lower than those found in the literature, namely 0.2, 0.5, and 1 mm to better approximate our study conditions to actual clinical situations where thinner layers are often used. Our results showed that the mean radiopacity degree (of the three thickness) of Amaris, Glacier, Grandio, Ice, P90, Rock, Supreme, Venus, Vit Escence, and Z350 was similar to that of enamel ($p > 0.05$). It is thus clinically infeasible to distinguish enamel and restoration at the tooth/restorative material interface with these composites. Consequently, imperfections may go undetected, ultimately leading to false positives or false negatives while diagnosing caries in this region (Table 2).

The radiopacity of Amelogen Plus, Aph, Brilhiante, Charisma, Concept Advanced, Evolux X, Exthet X, Inten S, Llis, Master Fill, Natural Look, Opallis, P60, Tetric, Tph, Z100, and Z250 was significantly higher than that of enamel ($p < 0.05$). With these composites, it is possible to observe the boundaries between restoration and tooth structure, thus affording confidence to the clinician in establishing a diagnosis of microleakage or restoration gap. These results are consistent with those of Hara et al[26] who have already demonstrated that the radiopacity of Z100 was higher than that of the tooth structure, and those of Salzedas et al,[7] who demonstrated that the radiopacity of Charisma, Z100, and Tph was equal to or higher than that of enamel.

The radiopacity of P90 was considered to be statistically similar to that of dentin ($p > 0.05$), which means it will not be possible to accurately distinguish dentin structures from restorative material at their interface when this material is used. The radiopacity of Amaris, Amelogen plus, Aph, Brilhiante, Charisma, Concept Advanced, Evolux X, Exthet X Glacier, Grandio, Ice, Inten S, Llis, Master Fill, Natural Look, Opallis, P60, Rock, Supreme, Tetric, Tph, Venus, Vit Escence, Z100, Z250, and Z350 was higher than that of dentin ($p < 0.05$).

The radiopacity of Durafill, on the other hand, proved lower than that of enamel and dentin ($p < 0.05$), rendering its clinical use difficult, insofar as it may be radiographically mistaken for a caries infiltration or for a restoration gap.

The only resin whose radiopacity was not significantly different from that of aluminum was Durafill ($p > 0.05$). These results show that, on average, this brand's radiopacity was statistically similar to that of aluminum, justifying its compliance with specification #27 of the ADA[27] and its place in the market. All other resins proved more radiopaque than aluminum ($p > 0.05$).

However, conditions closer to the clinical reality may be depicted by using different thickness. Table 3 shows the quantitative analysis of the different thicknesses of the materials. The radiopacity of the 0.2 mm test specimens made with the Durafill and Venus composites was lower than that of enamel and represents the worst results. The radiopacity of the 0.2 mm test specimens made with the Durafill composite was lower than that of dentin, confirming the results obtained when Durafill was compared with aluminum. The radiopacity of the 0.5 and 1 mm test specimens made with Durafill was lower than that of enamel, dentin, and aluminum. The thickness of the specimens may influence the observed radiopacity and, therefore, the similarity to enamel. Based on this observation, we suggest that further investigations be conducted on the radiopacity of this brand using specimens with different thicknesses.

CONCLUSION

All of the composite resins tested comply with specification #27 of the ADA.

The radiopacity of Amelogen Plus, Aph, Brilhiante, Charisma, Concept Advanced, Evolux X, Exthet X, Inten S, Llis, Master Fill, Natural Look, Opallis, P60, Tetric, Tph, Z100, and Z250 was significantly higher than that of enamel ($p < 0.05$). With these composites, it is possible to observe the boundaries between restoration and tooth structure, thus enabling clinicians to accurately establish a diagnosis of microleakage or restoration gap.

CLINICAL SIGNIFICANCE

Suitable radiopacity is an essential requisite for good-quality esthetic restorative materials. We demonstrate that only some composites have the sufficient radiopacity to observe the boundaries between restoration and tooth structure, which is the main cause of restoration failure.

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