Evaluation of the Radiopacity of Different Restorative Materials by the Digital Method

De Oliveira, Katharina Morant Holanda
Department of Pediatric Dentistry
School of Dentistry of Ribeirão Preto
University of São Paulo. Ribeirão Preto, São Paulo
Brazil

Almeida, Fernanda de Albuquerque

Beatrice, Lúcia Carneiro de Souza

Nascimento, Alexandre Batista Lopes

Teixeira, Hilcia Mezzalira
Department of Oral
Facial Prosthetics and Surgery.
School of Dentistry
Federal University of Pernambuco
Recife, Pernambuco
Brazil

Abstract

This study aimed to evaluate the radiopacity, by the digital method, of restorative materials. Five dental composite resins (Z350XT, ICE, Concept Advanced, Opallis and Evolu-X), five glass ionomer cements (GIC) (KetacN100, Vitremer, Riva Light Cure, VidrionR and MaxxionR) and one amalgam (GS-80) were evaluated. The samples and an aluminum stepwedge were placed on digital sensors and radiographed. The radiopacity was evaluated by the ImageJ software and analyzed by the Kruskal-Wallis test ($\alpha=0.05$). The results (radiopacity in thicknesses of aluminum) were: (mean ± SD): Z350XT (23.25 ± 4.22), ICE (17.79 ± 3.88), CA ($28.97 \pm 4, 32$), OP (22.5 ± 3.36), EX (9.54 ± 0.38), KN100 (5.84 ± 0.5), VIT (19.39 ± 11.54), RLC (11.42 ± 6.12), VID (8.14 ± 3.63), MAX (2.05 ± 0.17), amalgam (67.54 ± 6.03). It was possible to observe that all materials reached the 4049 ISO specifications for radiopacity, with the exception of the MAX GIC.

Keywords: composite resins; glass ionomer cements; radiographic image interpretation, computer-assisted.

Introduction

Composite resins are applied as restorative materials with great esthetic appeal due to approaching quite the natural features of teeth such as: color, texture, luster, translucency, and fluorescence. Besides its broad indication in many clinical situations, the use of dental esthetic restorative materials in posterior teeth brought significant developments in the area of operative dentistry at the end of the 20th century, allowing changes of several paradigms. Interestingly, one of the first recommendations for those restorations was the use of a glass ionomer as a liner [17].

Glass ionomer cements have been used for many clinical situations, such as restorations in deciduous teeth, base or liner material for internal reconstruction and even as material for retrograde radicular restoring. However, the first glass ionomer cements were radiolucent, fact that hindered its use on clinics [21].

Despite of their large use on operative dentistry, there is still a shortage in dental literature in radiopacity area, linked not only with the esthetic restorative materials, but with all materials that stay in liaison with the oral cavity [5], especially liners [8].

The radiopacity is one of the most desired and important properties in restorative materials, since it makes possible to distinguish the difference between the restorative material and secondary caries [9], cervical adaptation and appropriate proximal edges of restorations [3].

Improvement of properties of those materials, including radiopacity, has been the goal of the study of many authors [12, 15, 19]. To solve this problem, the manufacturers have used vitreous radiopacificators, which are incorporated into the restorative material as inorganic filler, such as barium, strontium, and zirconium [11]. The International Organization for Standardization (ISO) standard 4049 specifies that the radiopacity of dental restorative resins should be, for a specimen with 2 mm of thickness, equal to that of a 2 mm or larger thickness of aluminum [16]. In addition, The American Dental Association also requires commercial dental restorative resins to have a radiopacity at least equal to that of aluminum [1].

Due to constant need for information in the literature about the radiopacity of composite resins and glass ionomer cements, as well as the need for clinical update, this study aimed to evaluate the radiopacity degree of these materials and the amalgam *in vitro*. The initial hypothesis was that all materials would be in accordance with the 4049 ISO specifications for radiopacity. This study hopes to provide important fundamentals for the clinical choice that will satisfy the requirements of good radiopacity in the delineation of structures to be radiographed.

1. *Material And Methods*

Five composite resins and five glass ionomer cements were evaluated for the optical density. All materials are presented in table 1. For conducting the radiopacity study of composite resins and glass ionomer cements, five samples of each material were made with the aid of a tin-plate matrix according to the requirements laid down in rule 27 of the American Dental Association [1], with 10 mm of internal diameter, 2 mm of height and surrounding walls of approximately $8°$ of internal angle. It was also used an aluminum device to remove the samples of the matrix, trough the bottom face. After filling the matrix with each material, a 10 mm glass plate was pressed on the upper face, ensuring uniformity of surface and total filling.

The materials were light-cured through a wireless Radii-cal LED (SDI, Australia) with light curing time recommended by manufacturers. After the initial light curing, the matrix was opened and a second light curing was done on the opposite side, ensuring total polymerization of samples. For the samples of silver amalgam, capsules were mechanically crushed on Ultramat 2 (SDI), and condensed inside the array with the aid of an amalgam condenser nº 2 (S.S. White Duflex). The excess was removed with a Le Cron spatula (S.S. White Duflex). After, all the samples were measured with a digital paquimeter to ensure standardization of specimens. The samples were then stored in eppendorf tubes with distilled water at $37°$ C, with absolute humidity during 24h. Exposure to X-Rays was held at the equipment Dabi Atlante (Spectro 70x) with exposure time of 0.32 seconds. Above the phosphor plates, the samples of composite resins and glass ionomer cements were placed, besides a sample of amalgam and one aluminum stepwedge, which comes coupled with a sample of lead to the case of reads by conventional method. The set: phosphor plates, samples, and stepwedge was positioned on a fixed table and kept at a focus-film distance of 40 cm (Figure 1). The phosphor plates scanning were done on the SOREDEX – DIGORA OPTIME system (Milwaukee, Wisconsin, USA). Thus, Digital images were obtained of scanned phosphor plates (Figure 2).

For the reading of optical densities, it was used the software ImageJ 1.42q (National Institutes of Health, USA). Three random measures were carried out, in each specimen, resulting in an average of optical density. The values of liquid optical density (LOD) of each material and steps of the stepwedge were calculated. The LOD's aim is to establish the equivalence in millimeters of aluminum of the evaluated materials.

For the equivalence in millimeters of aluminum a chart was performed with inverse gray values versus Almm, to digital systems, obtaining the curve of radiopacity of the stepwedge steps, so, through an equation, it was obtained the value on the equivalence of Almm of the materials. For the curves construction, a mathematical approach was obtained, through an exponential trend curve, obtaining a value of R^2 the closer to 1, so the values of measures can be considered real.

The statistical analysis of the results was performed by the statistical measures: mean, median, standard deviation, coefficient of variation, minimum, and maximum values. Data was submitted to the SPSS v.15 (Statistical Package for the Social Sciences) software, by the The Kruskal-Wallis test with paired comparisons. The significance level adopted was 5%.

2. *Results*

The results of radiopacity, in thicknesses of aluminum, of the composite resins were (average ± SD): Z350XT (23.25 ± 4.22), ICE (17.79 ± 3.88), CA (28.97 ± 4.32), OP (22.5 ± 3.36), EX (9.54 ± 0.38). On the other hand, the results of radiopacity of the glass ionomer cements were: (average ± SD) KN100 (5.84 ± 0.5), VIT (19.39 ± 11.54), RLC (11.42 ± 6.12), VID (8.14 ± 3.63), MAX (2.05 ± 0.17). Statistics of radiopacity (Almm) of composite resins and glass ionomer cements are exposed in table 2. The amalgam value of radiopacity was (67.54 ± 6.03). The means of radiopacity according to the composite resins and to glass ionomer cements are in figure 3.

3. *Discussion*

For a correct radiographic analysis, some requirements are necessary to allow a good quality of radiographs. The use of scanned images and computer-aided radiographic image analysis with softwares especially designed for this purpose has allowed the development of radiopacity studies that are simple executed, reproducible and capable to provide reliable results [18]. The radiopacity is an important property of the restorative materials, once that enables the correct distinction among dental hard tissues and dental materials. On the clinics, it is very helpful to know accurately where the restorations are, their integrity and the occurrence of secondary caries and restorative marginal adaptation, for example [7, 20]. Thereby, the easy identification of the materials contributes to lower clinical time and correct diagnosis [5].

Several authors have reported that the ideal optical density for the restorative materials should be similar or slightly higher than enamel, with a large agreement in the literature [18, 22, 23]. Additionally, the ADA [1] recommends that the value of radiopacity required for restorative materials with 2 mm of thickness varies from 3 to 4 Almm. Although Willens et al. (1991) considered that the values of radiopacity must be equal or slightly superior to that of enamel, Curtis et al. (1990) [6] reported that the optical density values extremely high, as the metal restorations, can cover up suspected areas, interfering in the diagnosis of caries lesions, as well as cervical adaptation. This phenomenon is due to an optical illusion described by Berry (1983) [4], as *mach bands*, which are radiolucent areas along the junction cemento-enamel. This phenomenon may be influenced by the object's density, type of film and projections on the radiograph. Our study found high values of radiopacity for the amalgam, however, these values may not represent faithfully the thickness of aluminum equivalent, since this average may have extrapolated the base maximum value, thus proving to be excessive.

As the material thickness increases, produces major values of optical density [2, 6, 13, 18, 24]. To minimize this fact, in the present study, all samples were carried out with the same thickness of 2 mm. Furthermore, all samples of composite resins have been made in the A2 color of *Vita* scale, in attempt to eliminate the influence of possible different chemical compositions on the radiopacity. Many factors may influence on the values of optical density of the material, such as mean size thickness of load particles, chemical composition of the material, concentration of the components in the formulation of the restorative material, atomic number, among others.

In the present study, it was possible to observe that all composite resins had satisfactory enough values of optical density, with values between 9.54 to 28.97 Almm, and can therefore be easily differentiated in a radiographic interpretation of a dental element restored. The excellent radiopacity of Z350XT compsite can be due to the presence of silica-zirconia/nanoclusters. Although the EX composite had the smallest values of optical density, it has load particles with inorganic properties of borosilicate glass barium-aluminum (BABG), boron-aluminum fluoroborosilicate (BAFG) and silica particles.

The aluminosilicate glass is the basis of the definition as a glass ionomer material (ASPA: aluminosilicate poly-acrylate). However, incorporation of aluminosilicate glass alone makes glass ionomer materials radiolucent. Thus, it has been employed various radiopaque glasses (barium or strontium, i.e.) as powder components of glass ionomers in attempt to minimize this limitation. Among the glass ionomer cements, the RLC had the highest values of averages in Almm. Although the samples of VIT were built in A3 color of scale Vita, we observed that the average value in mm of aluminum was quite satisfactory. The glass ionomer cements KN100, VIT and VID presented satisfactory enough values due to the presence of radiopaque particles on their composition, like the silica-zirconia oxide in KN100, fluoraluminum silicate glass in VIT and Fluorosilicates of sodium, calcium, aluminum, and barium sulfate in the VID. Although the MAX presents in its composition particles of aluminum-fluorosilicate glass plus strontium glass, in the present study it had the lowest value of optical density. This findings are in agreement with other studies [2] where the GIC evaluated had lower values than the dental structure. This can be considered a disadvantage, because can result in difficulty of radiographic interpretation.

Hitij and Fidler (2013) [15] evaluated the radiopacity of 33 conventional resin composites, 16 flowable resin composites, and 7 glass ionomer cements comparing the results with the radiopacity values declared by the manufacturers and with teeth sections. The authors concluded that the radiopacity values of all 56 restorative materials were above the dentin reference radiopacity value, which could ravel the radiographic diagnosis of secondary caries, in addition to differences between the manufacturers' declared radiopacity values of some materials. Oztas et al. (2012) [19], evaluated the radiopacity of nine composite dental resin and eight dentin bonding. The authors compared the radiopacity values of the specimens with the tooth structure by means of films (transmission densitometer) and phosphor plates (Digora). The authors found excellent correlation between film and phosphor plates for both composite resins and bonding agents.

The radiopacity of restorative composites by conventional radiograph and digital images was evaluated with different resolutions. It was found that conventional radiograph was the most effective in enabling differentiation between enamel and composites and the high speed mode was the least effective in enabling radiographic differentiation between the dental tissues and restorative composites [7]. It is possible to found in literature a great number of authors [7, 15, 19] that compared the radiopacity of the restorative materials with dental structures. In the present study, the radiopacity values (Almm) of the composite resins and glass ionomer cements were analyzed in comparison with the 4049 ISO standard for radiopacity. It may be a limitation when comparing our results with other researches.

Heintze and Zimmerli (2011) [14] performed a review in three parts regarding the approval requirements and standardized testing of composite materials according to ISO specifications. About the radiopacity, the authors emphasize that radiopacity is an example of the suboptimal limits set by ISO standards, because the minimum values of 100%Al is too low for clinical use. According to Espelid and coworkers [10], a composite material must have a radiopacity of at least 200% Al to be distinguishable from dental hard tissues. Therefore, it is reasonable to direct future research towards clinical evaluation of radiopacity of restore materials related to the aging of the restorations and their integrity.

4. Conclusion

From the results obtained, it can be concluded that the radiopacity values in aluminum thickness of all composite resins were satisfactory according to the ISO recommendations. Additionally, the radiopacity values of glass ionomer cements were also satisfactory, with the exception of glass ionomer cement MAX, which presented values below the 4 Almm. Thus, it highlights that the operator must mind the radiopacity of the glass ionomer cements, once that they are very used as liners and as deciduous restorations. By the limitations of an *in vitro* experiment, more research should be conducted, especially clinic evaluations, regarding the radiopacity of the materials trough aging.

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Table 1: Groups, trade name, radio pacifier particle, indication and color of materials

Groups	Commercial name	Radiopacifier particle	Indication	Color
G1	Z350 XT – 3M ESPE (Campinas, SP, BR)	Zirconia/Silica nanoclusters	Universal	A2D
G2	ICE – SDI (Bayswater Victoria, VIC, AU)	Strontium glass	Universal	A2
G3	Concept Advanced (CA) – VIGODENT (Rio de Janeiro, RJ, BR)	Barium and aluminum silicate	Universal	A2
G4	Opallis (OP) – FGM (Joinville, SC, BR)	Barium glass-aluminum silicate silanizade and nanoparticles of silicon dioxide	Universal	A2
G5	Evolu-X (EX) – DENTSPLY (Petrópolis, RJ, BR)	Borosilicate Barium-aluminum glass (BBAG), boron-aluminum fluoroborosilicate (BAFG) and silica nanoparticled A and B	Universal	A2
G6	Ketac no 100 (KN100) – 3M ESPE (Irvine, CA, USA)	Silica-zirconia oxide	Restoration	A2
G7	Riva Light Cure (RLC) – SDI (Bayswater Victoria, VIC, AU)	SDI Technology: Ionglass ™	Restoration	A2
G8	Vitremer (VIT) – 3M ESPE	Fluoralumino silicate glass	Restoration	A3
G9	Vidrion R (VID) – SS WHITE (Rio de Janeiro, RJ, BR)	Fluorosilicates of sodium calcium aluminum sulfate	Restoration	U
G10	Maxxion R (MAX) – FGM (Joinville, SC, BR)	Glass particles of aluminofluorsilicato plus strontium glass	Restoration	A2
G11	GS-80 – SDI (Bayswater Victoria, VIC, AU)	Silver particles	-	-

Table 2: Radiopacity statistics (equivalence in Almm) between composite resins and between glass ionomer cements

Composites	Medium[1]	Median[1]	Standard deviation[1]	Coefficient of variation (%)	Minimum[1]	Maximum[1]
Z350 XT	23.25 [A]	22.48	4.22	18.15	19.55	30.42
ICE	17.79 [B]	17.21	3.88	21.81	13.70	24.20
CA	28.97 [C]	28.73	4.32	14.91	25.33	30.16
OP	22.50 [A]	22.92	3.36	14.93	17.80	26.50
EX	9.54 [D]	9.67	0.38	3.98	8.94	9.96
P value	$p^{(2)} < 0.001$*					
Glass ionomer cements	Medium[1]	Median[1]	Standard deviation[1]	Coefficient of variation (%)	Minimum[1]	Maximum[1]
KN100	5.84 [A]	5.69	0.50	8.56	5.32	6.38
RLC	19.39 [B]	25.85	11.54	59.52	5.89	29.31
VIT	11.42 [AB]	14.06	6.12	53.59	4.58	18.03
VID	8.14 [AB]	8.73	3.63	44.59	1.97	11.05
MAX	2.05 [C]	1.98	0.17	8.29	1.88	2.25
P value	$p^{(2)} = 0.009$*					

Different letters indicate statistical difference (A, B, C, D)

(*): Significant Difference to 5.0%.

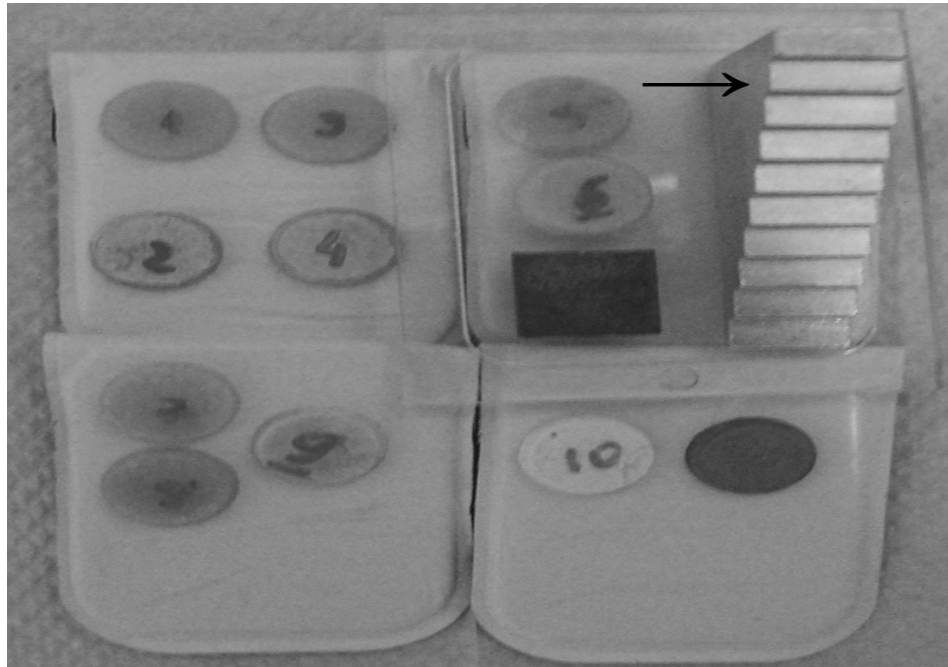(1): measures in Almm.

(2): through the Kruskal-Wallis test.

Figure 1: Materials placed on the phosphor plates. (Arrow indicates the aluminum step wedge).
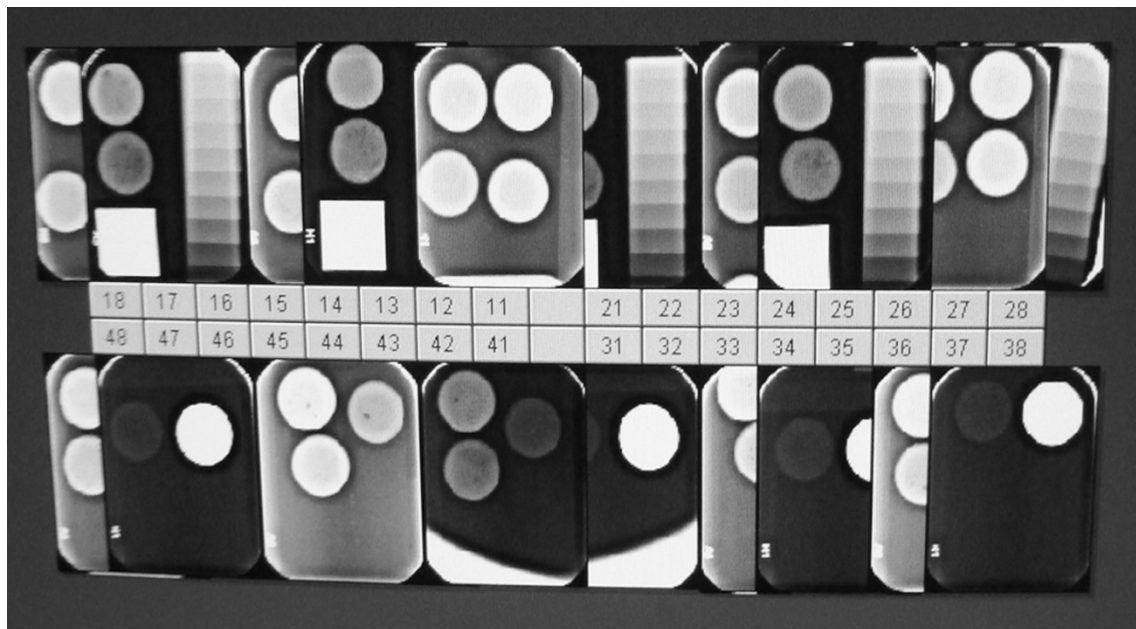

Figure 2: Evaluation of the optical density in Image J 1.42 q software (National Institutes of Health, USA).
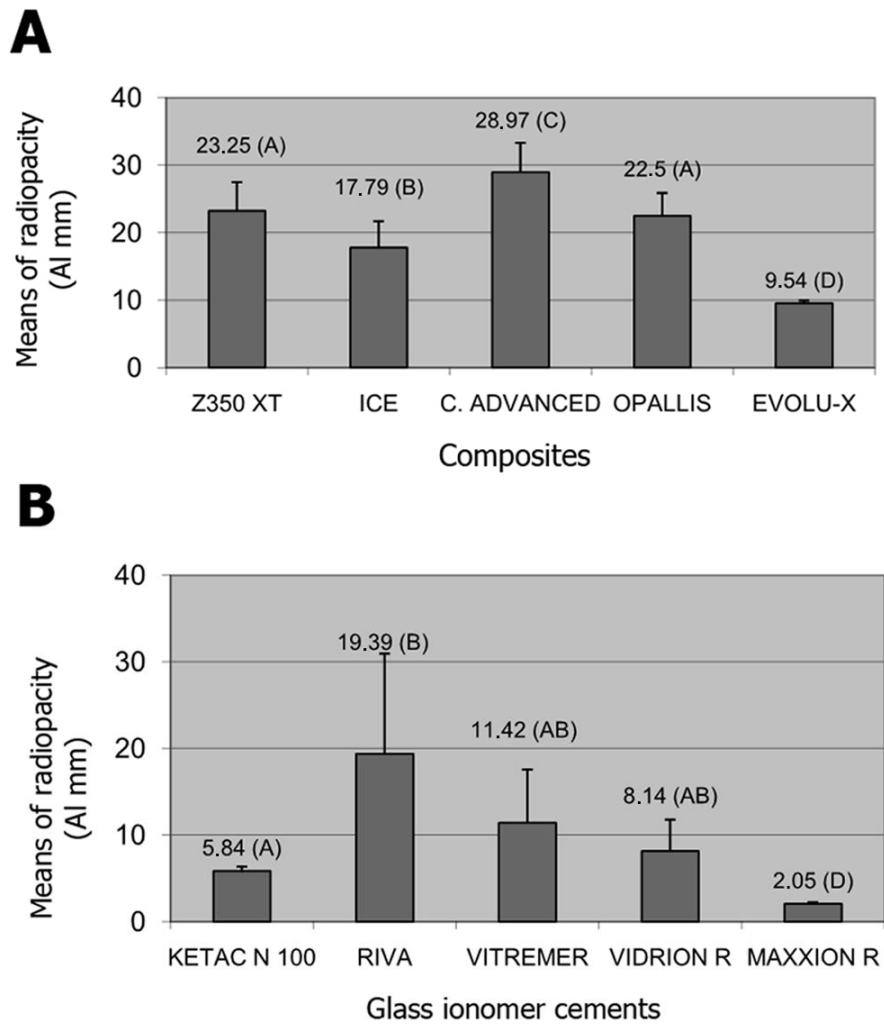
Figure 3: A: Average radiopacity of composite resins. B: Average radiopacity of glass ionomer cements.