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Evaluation of the optical density of composite resins with the use of nanotechnology by means of intraoral radiographic system (CMOS)

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ABSTRACT. The aim of this study was investigate the optical density of four different brands of composite resins of nanotechnology. The composite resins Estelite Sigma Quick® (Tokuyama), Esthet –X HD® (Dentsply), 4 Seasons® (Ivoclar Vivadent) and Filtek Z350XT™ (3M-ESPE) were inserted into cavities in transparent acrylic sheets, separated by thickness into 1, 2 and 3 mm. The images were imported into the software ImageTool® 3.0 (UTHSCSA, EUA). Data were submitted to ANOVA and Tukey. The mean values of the composite resins 4 Seasons® (2.71±0.20) and Filtek Z350XT™ (2.64±0.26) did not differ statistically for samples with thickness of 1 and 2 mm. However, for both thickness Estelite Sigma Quick® (1.92±0.11) and Esthet-X HD® (3.57±0.29) showed significant differences compared to the other composite resins ($p = .012$). All 3 mm-thick samples showed significant differences among themselves (Estelite Sigma Quick® $p < .001$, Esthet-X HD® $p < .001$, 4 Seasons® $p=.001$ and Filtek Z350XT™ $p = .003$). Conclusion: Among the three thicknesses evaluated, Estelite Sigma Quick® showed the lowest optical density, whereas the highest values were observed for Esthet X HD®. The resins are studied according to the rules of optical density value thus being favorable clinical use.

Keywords: diagnosis, radiographic image enhancement, dental materials, composite resins, nanotechnology.

Avaliação da densidade óptica de resinas compostas de nanotecnologia por meio de sistema radiográfico intraoral (CMOS)

RESUMO. O objetivo deste estudo foi investigar a densidade óptica de quatro diferentes marcas comercias de resinas compostas desenvolvidas com nanotecnologia. As resinas Estelite Sigma Quick® (Tokuyama), Esthet –X HD® (Dentsply), 4 Seasons® (Ivoclar Vivadent) e Filtek Z350 XT® (3M-ESPE) foram inseridas em orifícios existentes em placas de acrílico com espessuras de 1, 2 e 3 mm. As imagens foram importadas para o programa ImageTool® 3.0 (UTHSCSA, EUA). Os dados foram submetidos à análise de variância Anova e de Tukey. Nas espessuras de 1 e 2 mm, a média das resinas 4 Season® (2.71±0.20) e Z350XT® (2.64±0.26) não diferiram de forma estatística significante entre si ($p = .012$). No entanto, a Estelite Sigma Quick® (1.92±0.11) e a Esthet-X HD® (3.57±0.29) apresentaram diferenças estatisticamente significantes em relação a 4 Season® e Z350XT®. Na espessura 3 mm, todas apresentaram diferenças estatisticamente significantes entre si (Estelite Sigma Quick® $p < .001$, Esthet-X HD® $p < .001$, 4 Seasons® $p = .001$ and Filtek Z350XT™ $p = .003$). A Estelite Sigma Quick® apresentou os menores valores nas espessuras estudadas, os maiores valores observados na Esthet X HD®, para as três espessuras avaliadas. As resinas estudadas estão de acordo com a normativa de densidade óptica, portanto favorável ao uso clínico.

Palavras-chave: diagnóstico, radiologia digital, materiais dentários, resinas compostas, nanotecnologia.

Introduction

The optical density of composite resins is an important property for radiographic diagnosis (CURTIS JR. et al., 1990). According to the International Organization for Standardization (ISO) 4049, resins plates in thickness of 2 mm must present higher values than 2 mm EqAl determines that, in order for better distinction between tooth and restorative material, the optical density of composite resins must be greater than that of the human enamel (NOMOTO et al., 2008).

The search for improvement in diagnostic imaging led to the emergence of digital radiology. Among its benefits, digital radiology rationalized radiographic procedures, eradicated the use of the radiographic film and the need of wet chemical processing, which contributed to preservation of the environment, reduced radiation exposure without compromising image quality, enabled image manipulation based on the requirements of each medical area, even for underexposed images (BRENNAN, 2002), and made it possible to measure optical density of different materials in pixels (SABBAGH et al., 2004; CARVALHO-JUNIOR et al., 2007; BRAUN et al., 2008).

In 1981 the American Dental Association Council on Dental Materials and Devices (ADA, 1981), in accordance with specification n. 27 issued in 1977, stated that optical density is a necessary requirement in restorative materials. Optical density would assist the correct diagnosis of several clinical issues, such primary or secondary caries, excess of restorative material on the cervical margins of proximal surfaces, the proximal contour of restorations, the contact between the restorative material and the adjacent tooth, and the distinction between tooth and liner or restorative material of voids and cracks (CURTIS JR. et al., 1990; AKERBOOM et al., 1993; GU et al., 2006; DUKIĆ et al., 2012).

An important development in recent years has been the application of nanotechnology in dental composite resins, whose use has been spread extensively. Its particular composition, which combines high mechanical strength (ERGÜCÜ et al., 2010) to pleasing aesthetics, enables the use of nanoparticle composite resins for both anterior and posterior restorations (MITRA et al., 2003).

Nanotechnology also seems to facilitate the development of materials with greater optical density, which aids the diagnosis of secondary caries. Before the use of nanoparticles, the optical density of composite resins was attributed to glass particles of heavy metals, whose life expectancy can be compromised by hydrolysis. Tantalum oxide, which in the nanometer range performs as a monomer, presents an optical density similar to that of the enamel, regarded as showing the optimal optical density, and is biocompatible due to its high state of oxidation and resistance to extraction (CHAN et al., 1999).

Composite resins with the use of nanotechnology but different structural compositions offer the possibility of investigation whether they show distinct optical densities and how these densities would be expressed. If densities differ, it would help to distinguish composite resins among themselves, differentiate them from restorative materials, from dental structures and from possible teeth injuries and changes. A recent study (PEDROSA et al., 2011) found that composite resins with higher optical density than that of the enamel are more prone to false-negative diagnoses of secondary caries. However, despite the widespread use of these new materials, studies on their optical density are scarce.

Within this context, the present study aims to determine the optical density of four different brands of composite resins with the application of nanotechnology, with samples of different thicknesses, and the use of digital radiographic images.

Material and methods

Composite resins are comprised of a photopolymerizable organic matrix (Bis-GMA, UDMA, TEGDMA) and of inorganic elements of high atomic number (quartz, barium, strontium, zirconia, silicate) bonded by silane. Nanoparticles are added on composite resins with the application of nanotechnology, either in a dispersed or a clustered way (PAIC et al., 2008; CHEN et al. 2010).

Materials made of elements with low atomic number, as well as silicon, show radiolucency, whereas materials made of elements with high atomic number (Ba, Y, Yb, Zr, Sr) are more radiopaque (SABBAGH et al., 2004). This study used four light cured composite resins shade A3 from Vita™ Classic shade guide chart (Vita Zahnfabrik, Bad Säckingen, Germany): Estelite Sigma Quick®, Esthet –X HD®, 4 Seasons®, Filtek Z350 XT™. All of them presented at least one element that provided radiopacity (Table 1).

Table 1. Composite Resins - Technical specifications.

Composite resin	Classification	Manufacturer	Batch	Composition
Estelite Sigma Quick®	Supra-nano filled	Tokuyama, Tokyo, Japan	078E80	bis-GMA, TEGDMA fillers: 82% wt, zirconia/sílica particles
Esthet –X HD®	Nanohybrid	Dentsply, Konstanz, Germany	301513C	bis-GMA, TEGDMA, bis-EMA; barium fluoro alumino boro silicate glass
4 Seasons®	Nanohybrid	Ivoclar Vivadent, Schaan, Liechtenstein	N35672	bis-GMA, TEGMA, UDMA; 76% wt of barium glass filler, ytterbium trifluoride, Ba-Al-fluorsilicate glass and high dispersed silica
Filtek Z350 XT™	Nanoparticles	3M-ESPE Dental Products, St. Paul, MN, USA	1108800461	bis-GMA, UDMA, TEGDMA, PEGDMA, bis-EMA; 55,6% wt combination of non-agglomerated/non-aggregated silica filler, non-agglomerated/non-aggregated zirconia filler, and aggregated zirconia/silica cluster filler

The samples consisted of nine acrylic plates (10 x 30 mm), measured with a 0.01 mm-caliper, with thickness of 1, 2 and 3 mm, three plates for each thickness (DUKIĆ et al., 2013; CAVENAGO et al., 2013). The plates had four cavities of 5 mm diameter, and each cavity was filled with one of the four composite resins with a Thompson spatula n. 6 (Miltex, inc., Tuttlingen, Germany) following a pre-established order (Estelite Sigma Quick®, Esthet –X HD®, 4 Seasons®, Filtek Z350XT™).

In order to limit the thickness of the composite resins and level their surfaces, thus preventing the formation of bubbles, the material was pressed with a 5 mm-thick glass plate mediated by a plastic slide of the same size. The plates were protected by 0.012 mm-thick stretching and sticking PVC plastic film (Dispafilm do Brasil Ltda., Guarulhos, Sao Paulo State, Brazil) in order to prevent contamination.

An aluminum step wedge with eight steps (6063 alloy, ABNT, Brazil) was used in order to make the correspondence between the densities of the samples and that of the aluminum, in accordance with the requirements of ISO/DP 4049 (ISO, 2009) for optical density of resin-based materials.

Polymerization was performed with Optilight LD MAX® (Gnatus, Ribeirao Preto, São Paulo State, Brazil) for 20 s with curing light intensity of 420 mW cm^{-2}, the active tip of the photopolimerizer involving the entire surface of the composite resin, in accordance with the manufacturer's specifications. After curing, the samples were stored in test tubes, immersed in distilled water at 37°C for 24 hours in order to simulate the oral environment and complete the polymerization of the materials, as done by Ergücü et al. (2010).

The samples were radiographed beside the aluminum step wedge using a complementary metal–oxide semiconductor (CMOS) sensor of the Kodak® RVG 6100 Digital Radiography System (Carestream Health, New York, USA) and a dental X-ray machine (Dabi Atlante® Spectro 70X Eletronic, Ribeirao Preto, São Paulo State, Brazil). Nine radiographs were taken of each plate at a focus-film distance of 40 cm with an exposure time of 0.4 s, distance and exposure established subsequent to a pilot study (Figure 1).

The optical densities of the composite resins were analyzed with the program ImageTool® (version 3.0, UTHSCSA, USA). Optical density means were calculated based on the measurements taken in three different areas of each sample and on the fifth step of the step wedge (which corresponded to 5 mm). Thus, 15 measurements were taken for each sample, a total of 135. Results are expressed by means and standard deviations (M±SD), and between-group differences were verified with the use of One-Way Analysis of Variance (ANOVA) and post hoc Tukey for multiple comparisons of means.

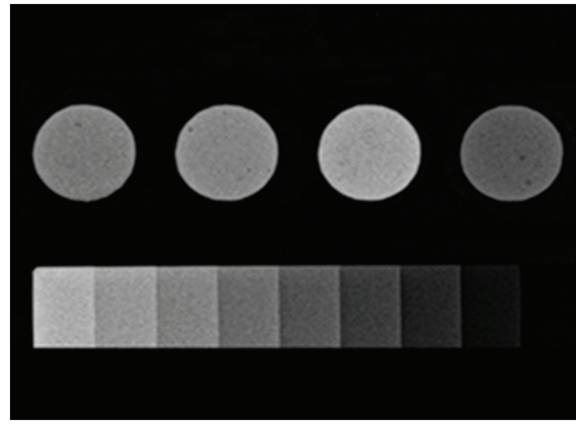

Figure 1. Radiographic image of the test plates in parallel positioned to the aluminum step wedge.

Results

Mean optical density differences, in mmEq Al^{-1}, are shown in the following figures and are represented by letters, with distinct letters standing for statistical differences. For the samples of 1 mm thickness (Figure 2), the values of 4 Seasons® (2.71±0.20) and of Filtek Z350XT™ (2.64±0.26) did not yield significance ($p = 0.012$). However, resins Estelite® Sigma Quick (1.92±0.11) and Esthet-X HD® (3.57±0.29) showed statistically significant differences from 4 Seasons® (2.71±0.20) and of Filtek Z350XT™ (2.64±0.26). Different letters indicate statistically significant difference (Figure 2).

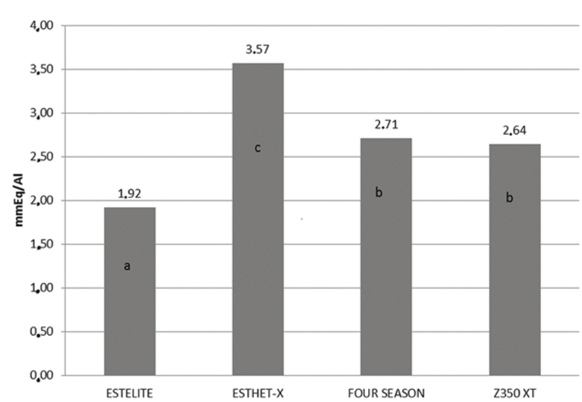

Figure 2. Composite resins of 1 mm thick with distinct letters standing for statistical differences.

Although the means were higher, composite resins of 2 mm thickness showed similar results to the samples of 1 mm (Figure 3). That is, the values of 4 Seasons® (6.68±0.33) and of Filtek Z350XT™ (6.00±0.19) were not significantly different, whereas ANOVA revealed that the means of Estelite Sigma Quick® (4.22±0.11) and of Esthet-X HD® (7.27±0.36) proved statistical ($p < .001$), both between each other and in comparison to the other composite resins.

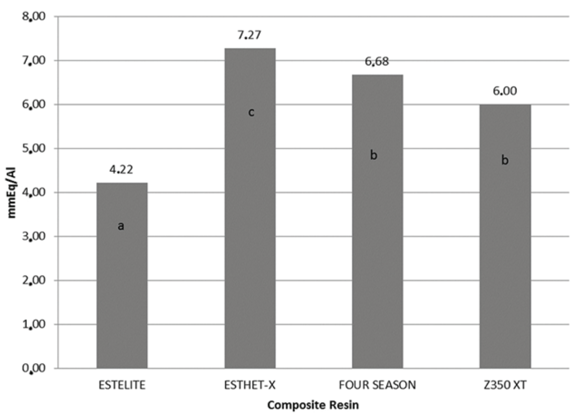

Figure 3. Composite resins of 2 mm thick with distinct letters standing for statistical differences.

All the means of the four composite resins of 3 mm thickness (Figure 4) showed statistical differences ($p < .001$), the highest value belonging to Esthet-X HD® (10.62±0.35), followed by 4 Seasons® (9.37±0.29), Filtek Z350XT™ (8.63±0.30), and Estelite Sigma Quick® (6.34±0.17).

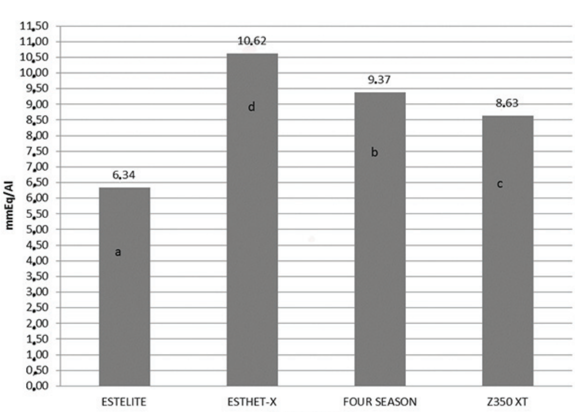

Figure 4. Composite resins of 3 mm thick with distinct letters standing for statistical differences.

Discussion

Several studies evaluated the optical density of dental materials of different thicknesses and with the use of different digital radiology programs for image analysis (TIRAPELLI et al., 2004; SALZEDAS et al., 2006; CRUVINEL et al., 2007; TSUGE et al., 2008; BALDEA et al., 2009; ERGÜCÜ et al., 2010, PEDROSA et al., 2011; WICHT et al., 2011). Ergücü et al. (2010), whose investigation method was similar to the present study, evaluated five brands of composite resins. The mean radiopacities of Filtek Supreme XT Flow®, Esthet X Flow® and Estelite Flow® were smaller than those found in the present study. However, the composite resins used by Ergücü et al. (2010) belong to a previous generation and present low viscosity (flowable), which might explain the conflicting results.

Different method was used by Sur et al. (2011), who evaluated the optical density of five composite resins (Sorare®, Estelite®, Gradia®, Clearfil®, Beautifil®), through linear attenuation coefficient, at different exposure times and speed. The composite resins showed greater coefficient than that of the dentine, that is, were more radiopaque than the dentine. These results diverge from those of Nomoto et al. (2008), who also employed linear attenuation coefficient to determine material optical density.

The present study radiographed each acrylic plate three times and performed three readings for each image, as done by previous studies of optical density (GÜRDAL et al., 1998; SABBAGH et al., 2004; FONSECA et al., 2006).

This study also evaluated samples with thickness of 3 mm given that larger restorations are more common in the clinical practice, and that restoring incipient caries is not necessarily needed (MITRA et al., 2003). Within the 3 mm-thick samples, all four composite resins showed statistical differences from one another, with increasing optical density means from Estelite Sigma Quick®, to Filtek Z350XT™, to 4 Season®, and to Esthet-X HD®. These results suggest that for larger cavities Esthet-X HD® is the best indication due to its highest optical density.

The ISO 4049 (2009) specification determines that the minimum optical density of a 2 mm-thick filling material should be equal or greater than that of a 2 mm-thick aluminun step wedge. In this study, the means of the composite resins of 2 mm thickness were all within ISO's 4049 (2009) specifications: Esthet-X HD® with the highest mean (7.67), followed by 4 Season® (6.56), Filtek Z350XT™ (6.01), and Estelite Sigma Quick® (4.26).

It is important to keep in mind, however, that differences in optical density of the same material found by different studies may be attributed to several factors, such as variations in exposure parameters, particularly in the potential voltage used in the x-ray machine (GU et al., 2006; PAIC et al., 2008; DUKIĆ et al., 2012), as well as in the purity of the aluminum (GU et al., 2006; PAIC et al., 2008; DUKIĆ et al., 2012) and in the thickness of the experimental material (SHAH et al., 1977).

The conflicting results suggest that the ideal optical density of the composite resins is a controversial issue. However, some authors (BOUSCHLICHER et al., 1999; MURCHISON et al., 1999; IMPERIANO et al., 2007) recommend that optical density higher than that of the dental structures are preferred for posterior restorations, given that the contrast helps to distinguish the interface between the restoration and the tooth. The composite resins with the application of nanotechnology used in this study demonstrated optical density sufficient to be safely used in the dental clinic, in accordance with the optical density requirements for esthetic restorative materials described in the literature.

Conclusion

The results of the present study showed that among the four composite resins and the three thicknesses, Estelite Sigma Quick® showed the lowest optical density means, whereas Esthet X HD® showed the highest means. As thickness increased, mean values of optical density also increased. The composite resins are within ISO's 4049 specifications.

References

ADA-American Dental Association. Council on dental materials, instruments and equipment of the American Dental Association. The desirability of using radiopaque plastics in dentistry: a status report. **Journal of American Dental Association**, v. 102, n. 3, p. 347-349, 1981.

AKERBOOM, H. B. M.; KREULEN, C. M.; VAN AMERONGEN W. E.; MOL A. Radiopacity of posterior composite resins, composite resin luting cements, and glass ionomer lining cements. **Journal Prosthetic Dentistry**, v. 70, n. 4, p. 351-355, 1993.

BALDEA, B.; FURTOS, G.; BRATU, D.; PREJMENREAN, C.; MOLDOVAN, M.; SILAGHI-DUMITRESCU, L. Radiopacity of flowable resin composite. **Journal of Oral Health and Dental Management**, v. 8, n. 4, p. 38-43, 2009.

BOUSCHLICHER, M. R.; COBB, D. S.; BOYER, D. B. Radiopacity of compomers, flowable and conventional resin composites for posterior restorations. **Operative Dentistry**, v. 24, n. 1, p. 20-25, 1999.

BRAUN, A. P.; SOARES, C. G.; CARRACHO, G. H.; COSTA, N. P.; VEECK, E. B. Optical density and chemical composition of microfilled and microhybrid composite resins. **Journal of Applied Oral Science**, v. 16, n. 2, p. 132-136, 2008.

BRENNAN, J. An introduction to digital radiography in dentistry. **Journal of Orthodontics**, v. 29, n. 1, p. 66-69, 2002.

CARVALHO-JUNIOR, J. R.; CORRER SOBRINHO, L.; CORRER, A. B.; SINHORETI, M. A. C.; CONSANI, S.; SOUSA NETO, M. D. Radiopacity of root filling materials using digital. Radiography. **International Endodontic Journal**, v. 40, n. 7, p. 514-520, 2007.

CAVENAGO, B. C.; PEREIRA, T. C.; DUARTE, M. A.; ORDINOLA-ZAPATA, R.; MARCIANO, M. A.; BRAMANTE, C. M.; BERNARDINELI, N. Influence of powder-to-water ratio on radiopacity, setting time, pH, calcium ion release and a micro-CT volumetric solubility of white mineral trioxide aggregate. **International Endodontic Journal**, v. 47, n. 2, p. 120-126, 2013.

CHAN, D. C. N.; TITUS, H. W.; CHUNG, K. H.; DIXON, H.; WELLINGHOFF, S. T.; RAWLS, H. R. Radiopacity of tantalum oxide nanoparticle filled resins. **Dental Materials**, v. 15, n. 3, p. 219-222, 1999.

CHEN, M. H. Update on dental nanocomposites. **Journal of Dental Research**, v. 89, n. 6, p. 549-560, 2010.

CRUVINEL, D. R.; GARCIA, L. F. R.; CASEMIRO, L. A.; PARDINI, L. C.; SOUZA, F. C. P. P. Evaluation of radiopacity and microhardness of composite submitted to artificial aging. **Materials Research**, v. 10, n. 3, p. 325-329, 2007.

CURTIS JR., P. M.; VON FRAUNHOFER, J. A.; FARMAN, A. G. The radiographic density of composite restorative resins. **Oral Surgery Oral Medicine Oral Pathology**, v. 70, n. 2, p. 226-230, 1990.

DUKIĆ, W., DELIJA, B.; DEROSSI, D.; DADIC, I. Radiopacity of composite dental materials using a digital X-ray system. **Dental Materials Journal**, v. 31, n. 1, p. 47-53, 2012.

DUKIĆ, W.; DELIJA, B.; LEŠIĆ, S.; DUBRAVICA, I.; DEROSSI, D. Radiopacity of flowable composite by a digital technique. **Operative Dentistry**, v. 38, n. 3, p. 299-308, 2013.

ERGÜCÜ, Z.; TÜRKÜN, L. S.; ÖNEM, E.; GÜNERI, P. Comparative radiopacity of six flowable resin composites. **Operative Dentistry**, v. 35, n. 4, p. 436-440, 2010.

FONSECA, R. B.; BRANCO, C. A.; SOARES, P. V.; CORRER SOBRINHO, L.; HAITER NETO, F.; FERNANDES NETO, A. J.; SOARES, C. J. Radiodensity of base, liner and luting dental materials. **Clinical Oral Investigations**, v. 10, n. 2, p. 114-118, 2006.

GU, S.; RASIMICK, B. J.; DEUTSCH, A. S.; MUSIKANT, B. L. Radiopacity of dental materials using a digital X-ray system. **Dental Materials**, v. 22, n. 8, p. 765-770, 2006.

GÜRDAL, P.; AKDENIZ, B. G. Comparison of two methods for radiometric evaluation of resin-based restorative materials. **Dentomaxillofacial Radiology**, v. 27, n. 4, p. 236-239, 1998.

IMPERIANO, M. T.; KHOURY, H. J.; PONTUAL, M. L.; MONTES, M. A. J.; SILVEIRA, M. M. F.

Comparative radiopacity of four low-viscosity composites. **Brazilian Journal of Oral Sciences**, v. 6, n. 20, p. 1278-1282, 2007.

ISO-International Organization for Standardization. ISO 4049. ISO-Standards. **Dentistry - polymer-based restorative materials**. Geneva: ISO, 2009.

MITRA, S. B.; WU, D.; HOLMES, B. An application of nanotechnology in advanced dental materials. **Journal of American Dental Association**, v. 134, n. 10, p. 1382-1390, 2003.

MURCHISON, D. F.; CHARLTON, D. G.; MOORE, W. S. Comparative radiopacity of flowable resin composites. **Quintessence International**, v. 30, n. 3, p. 179-184, 1999.

NOMOTO, R.; MISHIMA, A.; KOBAYASHI, K.; MCCABE, J. F.; DARVELL, B. W.; WATTS, D. C.; MOMOI, Y.; HIRANO, S. Quantitative determination of radio-opacity: equivalence of digital and film X-ray systems. **Dental Materials**, v. 24, n. 1, p. 141-147, 2008.

PAIC, M.; SENER, B.; SCHUG, J.; SCHMIDLIN, P. R. Effects of microabrasion on substance loss, surface roughness, and colorimetric changes on enamel in vitro. **Quintessence International**, v. 39, n. 6, p. 517-522, 2008.

PEDROSA, R. F.; BRASILEIRO, I. V.; PONTUAL, M. L. A.; SILVEIRA, M. M. Influence of materials radiopacity in the radiographic diagnosis of secondary caries: evaluation in film and two digital systems. **Dentomaxillofacial Radiology**, v. 40, n. 6, p. 344-350, 2011.

SABBAGH, J.; VREVEN, J.; LELOUP, G. Radiopacity of resin-based materials measure in film radiographs and storage phosphor plate (Digora). **Operative Dentistry**, v. 29, n. 6, p. 677-684, 2004.

SALZEDAS, L. M.; LOUZADA, M. J.; OLIVEIRA FILHO, A. B. Radiopacity of restorative materials using digital images. **Journal of Applied Oral Science**, v. 14, n. 2, p. 147-152, 2006.

SHAH, P. M.; SIDHU, S. K.; CHONG, B. S.; FORD, T. R. Radiopacity of resin-modified glass ionomer liners and bases. **Journal of Prosthetic Dentistry**, v. 77, n. 3, p. 239-242, 1997.

SUR, J.; ENDO, A.; MATSUDA, Y.; ITOH, K.; KATOH, T.; ARAKI, K.; OKANO T. A measure for quantifying the radiopacity of restorative resin. **Oral Radiology**, v. 27, n. 1, p. 22-27, 2011.

TIRAPELLI, C.; PANZERI, F. C.; PANZERI, H.; PARDINI, L. C.; ZANIQUELLI, O. Radiopacity and microhardness changes and effect of X-ray operating voltage in resin-based materials before and after expiration date. **Materials Research**, v. 7, n. 3, p. 409-412, 2004.

TSUGE, T.; KAWASHIMA, S.; HONDA, K.; KOIZUMI, H.; MATSUMURA, H.; HISAMATSU, N. Radiopacity of anterior and posterior restorative composite. **International Chinese Journal of Dentistry**, v. 8, n. 4, p. 49-52, 2008.

WICHT, S.; PFEIFFER, P.; ROTHER, U.; NERGIZ, I.; SCHMAGE, P. Gray value differences to dentin of root posts radiographed with digital intraoral systems and conventional x-ray films. **Operative Dentistry**, v. 36, n. 1, p. 27-35, 2011.

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