



A new assessment methodology to evaluate the radiopacity of endodontic filling materials

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Abstract

Objective: To evaluate the radiopacity of endodontic filling materials using a new experimental *in vitro* model.

Methods: To prevent the overlapping of tissues and anatomical structures, a tissue simulator block was created. Gutta-percha, Resilon cones and polyethylene tubes filled with Epiphany, AH Plus and EndoFill (n=5 of each material) were placed inside the root canal of a tooth positioned in the simulator and radiographed after setting. Five sealer samples were prepared in standard discs and radiographed after setting. The films were processed and digitized. The digital images were analyzed using Adobe Photoshop[®] software; the grayscale values (0 to 256 pixels) were compared using Wilcoxon and Mann-Whitney tests ($P < 0.05$) for the cones and ANOVA, Tukey, independent and dependent t tests ($P < 0.05$) for the sealers.

Results: In the simulator, AH Plus and Epiphany behaved similarly, presenting higher gray values than those presented by Endofill. In the standard discs, AH Plus was the most radiopaque, followed by Epiphany and Endofill. Resilon presented with higher radiopacity than did gutta-percha, while both were higher than dentin was.

Conclusion: All endodontic filling materials presented higher gray values than dentin did, allowing them to be distinguished from the tooth and its surrounding structures. The proposed methodology can be used for the assessment of the radiopacity of endodontic filling materials.

Keywords: endodontics; radiology; radiopacity; root canal filling materials.

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Avaliação da radiopacidade de materiais de obturação endodônticos utilizando um novo modelo experimental.

Resumo

Objetivo: Avaliar a radiopacidade dos materiais de obturação endodônticos usando um novo modelo experimental *in vitro*.

Metodologia: Considerando a sobreposição dos tecidos e estruturas anatômicas, um bloco simulador de tecidos foi criado. Cones de Guta-percha e Resilon e tubos de polietileno preenchidos pelos cimentos Epiphany, AH Plus e Endofill (n=5 de cada material) foram posicionados dentro de um canal radicular de um dente que foi posicionado no simulador e radiografias foram realizadas. Além disso, cinco amostras de cada cimento foram preparadas em discos padronizados e radiografadas. Os filmes foram processados e digitalizados. As imagens digitais foram analisadas pelo programa Adobe Photoshop[®] e valores de escala de cinza (0 a 256 pixels) foram comparados usando os testes Wilcoxon e Mann-Whitney ($P < 0,05$) para avaliar os cones e ANOVA, Tukey, Testes t independente e dependente ($P < 0,05$) para avaliar os cimentos.

Resultados: No simulador de tecidos, o AH Plus e o Epiphany se comportaram semelhantemente, apresentando valores de cinza maiores do que o Endofill. Nos discos padronizados, o AH Plus foi o cimento mais radiopaco, seguido pelo Epiphany e Endofill. Os cones de Resilon se mostraram mais radiopacos do que a gutta-percha e ambos mais do que a dentina.

Conclusão: Todos os materiais obturadores endodônticos apresentaram valores de cinza maiores do que a dentina, o que permite distingui-los do dente e das estruturas anatômicas em sua volta. A metodologia proposta pode ser usada para avaliação a radiopacidade de materiais obturadores endodônticos.

Palavras-chave: Endodontia, radiologia, radiopacidade, materiais obturadores

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Introduction

Among other physical/chemical properties, an ideal root canal sealing material should display sufficient radiopacity to allow radiographic assessment and to be able to distinguish the material from the tooth and its surrounding structures. Previous studies indicated that gutta-percha cones and most endodontic sealers exceeded the minimal radiopacity requirement [1-4]. However, the absence of an ideal root filling material has stimulated the development of new products, and the radiopacities of these new products warrant evaluation.

Eliasson and Haasken [5] were the first to establish a standardized method for radiopacity measurements in dentistry. This traditional methodology evaluated endodontic filling materials without considering the overlapping of tissues and anatomical structures. The absence of bony trabeculae and soft tissues constitutes an important differential in relation to clinical situations when the radiopacity is being investigated, as it may alter the perception of the radiopacity of dental materials [6].

Due to these limitations, alternative methods must be suggested. The advent of image digitalization enables the use of specific software to determine the gray pixel values [7]. Moreover, Gessler and Fontanella [6] developed a "tissue simulator block" that specifically simulated clinical conditions. This experimental model has already been successfully used in studies on the diagnosis of external apical root resorption, although it has not been used to evaluate the radiopacity of endodontic materials [6,8].

Therefore, the aim of this study was to assess the radiopacity of three endodontic sealers (a zinc oxide and eugenol-based sealer (Endofill) and two resin-based sealers (AH Plus and Epiphany)), as well as gutta-percha and Resilon cones, using a new experimental *in vitro* model.

Material and Methods

The present study was approved by the Ethics Committee of the Federal University of Rio Grande do Sul (Brazil).

To simulate a clinical situation as precisely as possible, a tissue simulator block was created [6]. The maxilla of a human skull was used, and the separation of its anterior region was obtained using a diamond double-faced disc (KG Sorensen, Barueri, SP, Brazil). The obtained part was divided into two parts via sagittal osteotomy, resulting in buccal and palatal segments.

The segments were fixed with wax (Wilson, São Paulo, SP, Brazil) in a plastic container (length=6 cm, width=2.5 cm, depth=3.5 cm). Distances of 1 cm were established between the external surfaces of the buccal and palatal segments and the container's walls. This space was later filled with a pored acrylic self-curing material (Artigos Odontológicos Clássico, São Paulo, SP, Brazil) that would simulate the soft tissues.

A distance of 0.5 cm was established between the internal surface of the buccal bone and the internal surface of the

palatal bone. The space was filled with wax, which was used to fix a human canine root with a previously prepared root canal. The root was inserted up to the point where the cemento-enamel junction coincided with the level of the alveolar crest. The distances between the bone segments and the wax filling permitted the simulation of the periodontal ligament.

To evaluate the radiopacity of Epiphany (Pentron Clinical Technologies, Wallingford, CT, USA), AH Plus (De Trey – Dentsply, Konstanz, Germany) and Endofill (Dentsply HERO Indústria e Comércio Ltda, Petrópolis, RJ, Brazil), the endodontic sealers were prepared according to their manufacturers' instructions. The freshly mixed sealer was introduced into polyethylene tubes (10 mm × 1.5 mm; Abbott Lab do Brasil, São Paulo, SP, Brazil) and into acrylic wells (standard disc with 3 mm of thickness × 4 mm in diameter) with a syringe to avoid bubbles. The acrylic wells were placed over a glass plate covered with a cellophane sheet. The tubes and plates with the sealers were stored in a moist chamber at 37°C for seven days for setting.

The tubes with the sealers, gutta-percha and Resilon cones (n=5 for each material) were placed in the root canal of the tooth that was positioned in the tissue simulator before being radiographed. Periapical films (Insight; Eastman-Kodak Co, Rochester, NY, USA) were taken at a distance of 20 cm from the radiation source using an apparatus (Timex 70C, Gnatus, Ribeirão Preto, SP, Brazil) set to work at 66 kVp, 6.5 mA and 0.5 seconds.

The standard discs with the sealers (n=5) were also radiographed.

The films were processed in a deep tank with new X-ray solution (Kodak, Rochester, NY, EUA), which was maintained at a constant temperature, and digitized using a flatbed scanner with a transparency adapter (Epson Perfection 2450[®], Long Beach, CA, USA). A black acrylic mask, which standardized the positioning of the film on the surface of the scanner, was used to limit the area of light incidence. The images were captured at their original size, using 300 dpi and 8 bit mode, provided 256 gray levels and were stored in JPEG format with a 3:1 compression ratio.

To obtain the optical density values, the digital images were analyzed with the Adobe Photoshop[®] software (v. 8.0, Adobe Systems, San José, EUA), using the histogram tool.

For cone evaluation, an area of interest (336 pixels) in the cervical one-third of the root canal was selected before the images of the cone and dentin of the root were obtained.

For the evaluation of the endodontic sealers, an area of interest was selected from each sample. A standard size circle was drawn in the center of the standard disc (Fig. 1). In the images obtained by the tubes, two standard size rectangles, one under the tube and another under the dentin, were drawn on the cervical third of the root (Fig. 1).

The average and standard deviation of the grayscale pixel values – 0 (black) to 256 (white) – of the area selected were measured and registered. Radiopaque materials were considered to have higher values, whereas radiolucent materials were thought to have lower values.

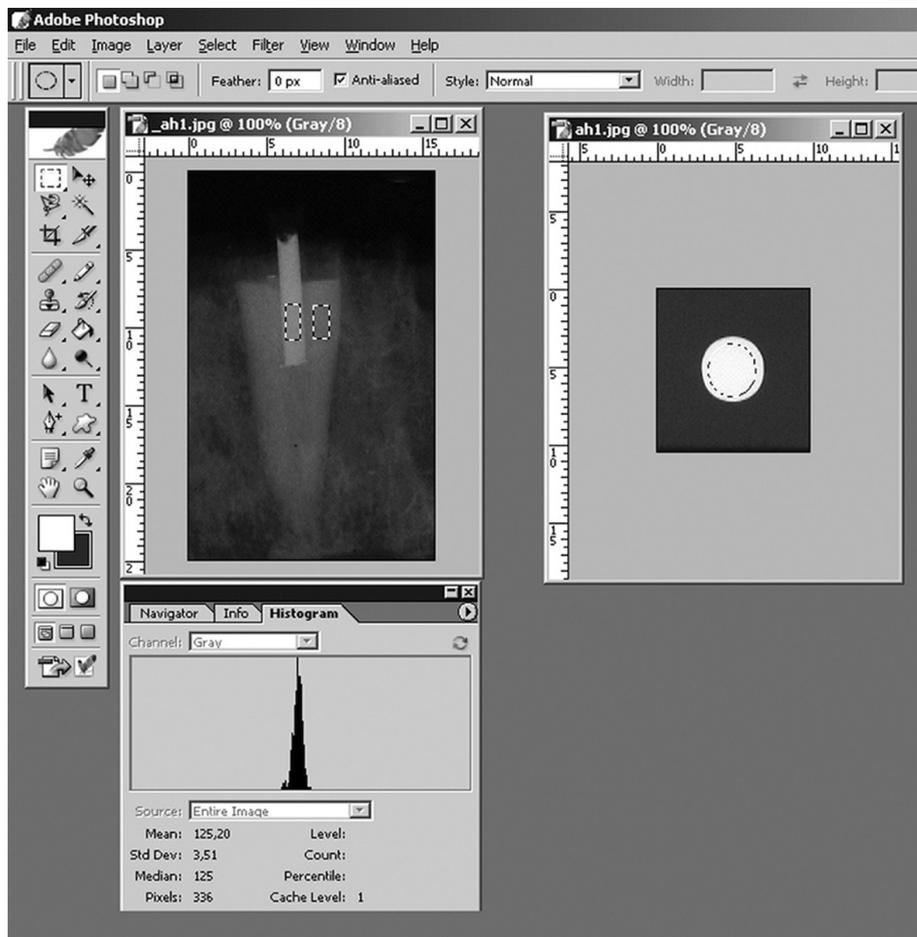


Fig. 1. Adobe Photoshop® software showing the image obtained of tubes and standard discs methods and areas of interest selected.

To compare the radiopacity between the sealers, each method was considered independently, and the data were subjected to a statistical analysis using a one-way analysis of variance (ANOVA) and a Tukey test. To compare both methods, the data were evaluated using an independent t-test. To compare the data obtained from the dentin and sealers in the tubes method, a dependent t-test was used.

The Wilcoxon statistical test was used to compare the radiopacity between the cones and the dentin, while the Mann-Whitney test was used to compare the gutta-percha and Resilon cones.

The significance level was set at 5%, and the data were processed using SPSS version 10.0.

Results

The data obtained with the simulator demonstrated that AH Plus and Epiphany behaved similarly, displaying higher gray values than Endofill did and indicating superior radiopacity. All of the tested sealers showed higher radiopacity than that of dentin ($P < 0.05$) (Table 1).

Standard discs exhibited significantly higher gray values compared with the sealers in the simulator ($P < 0.05$). AH Plus was the most radiopaque material, followed by Epiphany and Endofill ($P < 0.05$) (Table 2).

Table 1. Mean and standard deviation (SD) of the grayscale values (pixels) in the tubes containing the sealers (AH Plus, Epiphany, Endofill) and to dentin in the simulator.

Sealer	Tube	Dentin
	Mean ± SD*	Mean ± SD*
AH Plus	126.47 (±3,86) ^{Aa}	96.43 (±3,86) ^B
Epiphany	124.56 (±2,87) ^{Aa}	97.51 (±3,69) ^B
Endofill	109.53 (±2,87) ^{Ba}	93.20 (±0,69) ^B

* Different capital letters indicate a statistically significant difference between sealers (ANOVA, Tukey $P < 0.05$).

* Different lower letters indicate a statistically significant difference between sealers and dentin (Dependent t-Test $P < 0.05$).

Table 2. Mean and standard deviation (SD) of the grayscale values (pixels) to the sealers (AH Plus, Epiphany, Endofill), according to the method.

Sealer	Standard discs		Tubes	
	Mean ± SD*		Mean ± SD*	
AH Plus	241.19 ± 4.65	Aa	126.47 ± 3.86	Ab
Epiphany	224.92 ± 3.80	Ba	124.56 ± 2.87	Ab
Endofill	205.04 ± 0.75	Ca	109.53 ± 2.87	Bb

* Different capital letters indicate a statistically significant difference between sealers to each method (ANOVA, Tukey $P < 0.05$).

* Different lower letters indicate a statistically significant difference between methods to each sealer independently (Independent t-Test $P < 0.05$).

Resilon cones presented with higher gray values than the gutta-percha cones did, indicating superior radiopacity ($P < 0.05$). Dentin exhibited an inferior gray value relative to the tested materials ($P < 0.05$) (Table 3).

Table 3. Mean values and standard deviation of the grayscale values (pixels) for gutta-percha, Resilon cones and dentin.

Gutta-percha	Dentin	Resilon	Dentin
125.67 ^{A*}	112.46 ^B	131.93 ^{***}	111.98 ^B
±0.45	±0.56	±0.41	±0.48

[†] Different capitals letters indicate that gutta-percha and dentin differs significantly ($P = 0.043$) and different lower letters indicate that Resilon and dentin differs significantly ($P = 0.043$) by Wilcoxon test; different number of asterisks indicate that gutta-percha and Resilon differs significantly ($P = 0.008$) by Mann-Whitney test.

Discussion

The present investigation showed, as expected, the loss of radiopacity of endodontic sealers in the setting of overlapping tissues and anatomical structures. In this context, the presence of bony trabeculae and soft tissues is an important feature when radiopacity is being investigated [6,9]. Additionally, radiopacity of root canal sealers has been of particular significance for the evaluation of the quality of endodontic treatment, and it is also helpful in the assessment of possible voids in obturation [10-12].

The sealers in the standard discs displayed higher gray values than did those obtained in the tubes inside the simulator tissue block. Furthermore, higher gray values were measured for sealers than for dentin in both methods, demonstrating that these materials present enough radiopacity to be identified under clinical conditions.

It is important to note that the zinc oxide and eugenol-based sealer (Endofill) showed lower radiopacity than the two resin-based sealers did, independent of the method adopted for evaluation. Similar results were found by Sydney et al. (2008) [13].

Differences between AH Plus and Epiphany were observed only when these materials were evaluated in standard discs. As was shown in previous studies [4,14-16], AH Plus presented with superior results compared to the other resin-based sealers. Unlike the results presented herein, Garrido et al. [17], did not find differences between AH Plus and Endofill when using standard discs.

In this regard, the observed differences may be related to the radiopacity agents. The Endofill sealer contains bismuth subcarbonate and barium sulfate [17]; AH Plus contains zirconium oxide, iron oxide and calcium tungstate [11,15]; and Epiphany contains silane-treated barium-borosilicate glass in addition to barium sulfate, bismuth and silica [18].

The gutta-percha and Resilon cones presented with higher gray pixel values compared with dentin. Moreover, Resilon cones showed higher values of optical density than gutta-percha did.

The comparison of the two assessment methods for the sealer radiopacity tests validated the use of a tissue simulator block, especially when clinical conditions are considered. The choice of imaging system may affect the radiopacity measurements [19], although the use of digitized images is a viable option for the analysis of the radiopacity of endodontic sealers [20]. The methodology used in the present study is simple and accessible and can provide reliable results.

Conclusion

The results of the present study demonstrated that all sealers showed appropriate values of radiopacity, presenting with higher values than those of dentin, which enables these materials to be distinguished from the tooth and its surrounding structures. AH Plus was the most radiopaque material, independent of the method used. The methodology proposed for simulating clinical situations was found to be adequate for the assessment of the radiopacity of dental materials.

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