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Evaluation of the radiopacity of calcium hydroxide- and glass-ionomer-based root canal sealers

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Abstract

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Aim To evaluate the radiopacity of calcium hydroxide-based root canal sealers (Acroseal, Sealapex and Sealer 26), a glass-ionomer-based sealer (Activ GP Sealer) and a zinc oxide and eugenol-based sealer (Intrafill).

Methodology Five disc-shaped specimens (10 × 1 mm) were fabricated from each material, according to the International Organization for Standardization (ISO) 6876/2001 standard. After setting of the materials, radiographs were taken using occlusal films and a graduated aluminum step-wedge varying from 2 to 16 mm in thickness. The dental X-ray unit (GE1000) was set at 50 Kvp, 10 mA, 18 pulses s^{-1} and distance of 33.5 cm. The radiographs were digitized and the radiopacity compared with that of the aluminum step-wedge, using WIXWIN-2000 software (Gendex). Data (mm Al) were submitted to ANOVA and Tukey test.

Results Intrafill was the most radiopaque material (7.67 mm Al) followed by Sealer 26 (6.33 mm Al), Sealapex (6.05 mm Al) and Acroseal (4.03 mm Al). Activ GP was the least radiopaque material (1.95 mm Al, $P < 0.05$).

Conclusions The sealers evaluated in this study had different radiopacities. However, except for the glass-ionomer-based sealer, all materials had radiopacity values above the minimum recommended by the ISO standard.

Keywords: radiology, radiopacity, root canal filling materials.

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Introduction

Ideally, root canal sealers should present, among other physicochemical properties, sufficient radiopacity to be distinguished from adjacent anatomical structures (McComb & Smith 1976, Beyer-Olsen and Ørstavik 1981, Katz *et al.* 1990, Imai & Komabayashi 2003), such as dentine and bone (Laghios *et al.* 2000). Higginbotham (1967) was the first to publish a study comparing the radiopacity of various endodontic sealers and gutta-percha cones used for root canal filling. Later, Eliasson & Haasken (1979) established a comparison standard for radiopacity studies in which the optical radiographic densities of several impression materials were measured and the values expressed as an equivalent thickness of aluminum capable of producing similar radiographic density.

Beyer-Olsen & Ørstavik (1981) included in their studies a reproducible comparison standard using a 2-mm-increment aluminum step-wedge to determine the radiopacity of several root canal sealers. Their results showed that most investigated materials were more radiopaque than dentine. Tanomaru-Filho *et al.* (2007) evaluated the radiopacity of five root canal sealers (AH Plus, Intrafill, Roeko Seal, Epiphany and EndoRez) using a graduated aluminum step-wedge varying from 2 to 16 mm in thickness. AH Plus and

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Epiphany were the most radiopaque materials, followed by EndoRez, Roeko Seal and Intrafill. Although the tested materials had different radiopacities, all of them had values above the minimum recommended by the ISO.

New endodontic sealers have recently been proposed as innovative filling materials. Among the new root canal sealers are Acroseal and Activ GP Sealer (based on glass-ionomer). It is important to evaluate their physical and chemical properties, including radiopacity.

Acroseal (Specialités-Septodont, Saint Maur-des-Fossés, Cedex, France) is a calcium hydroxide-based sealer with epoxy resin, which has been shown to have low toxicity (Gambarini *et al.* 2003) and excellent film thickness (Testarelli *et al.* 2003). Sealer 26 is an epoxy resin-based endodontic sealer, composed of bismuth oxide, calcium hydroxide and epoxy resin. Sealer 26 is known for its excellent sealing properties (Siqueira *et al.* 2001).

Sealapex (SybronEndo, Orange, CA, USA) is a calcium hydroxide-based sealer that has good biological properties (Holand and Souza 1985, Leonardo *et al.* 1997, Tanomaru-Filho *et al.* 1998) and apical sealing capacity (Cobanhara *et al.* 2006). The manufacturer of Sealapex has recently modified its formulation by adding bismuth trioxide to improve its radiopacity and increase its shelf life.

Activ GP Sealer (Brasseler Inc., Savannah, GA, USA) is a glass-ionomer-based material indicated for use together with Activ GP^{TM} gutta-percha points, which provide adhesion between the filling material and the root canal walls.

The aim of this study was to compare the radiopacity of new root canal sealers (Acroseal, Activ GP Sealer and Sealapex with new formulation) and traditional root canal sealers (Intrafill and Sealer 26), according to the International Organization for Standardization ISO 6876 (2001), which recommends that root canal filling materials should be at least as radiopaque as 3 mm thickness of aluminium.

Materials and methods

Five root canal sealers were evaluated in this study: Acroseal, Sealapex, Sealer 26, Activ GP Sealer and Intrafill (Table 1). The materials were prepared according to the manufacturers' instructions. Five disc-shaped specimens (10 mm diameter; 1 mm thick) were fabricated from each material. For such purpose, metallic matrices were made and impressions were taken using a light-bodied silicone-based impression material. The impressions were filled with the sealers and stored in a moist chamber (incubator) at 37 °C for 48 h until complete setting of the materials.

Thereafter, the specimens were positioned on five occlusal radiographic films (Insight – Kodak Corp, Rochester, NY, USA) and exposed along with an aluminum step-wedge with variable thickness (from 2 to 16 mm, in 2 mm increments). A GE-1000 X-ray unit (General Electric, Milwaukee, WI, USA) operating

Table 1 Tested materials

Product	Composition	Manufacturer
Acroseal	Hexamethylenetetramine (methenamine), enoxolone, bismuth subcarbonate, colophane, terebinthina, venice turpentine, calcium hydroxide, bisphenol A diglycidyl ether, pigment.	Specialités-Septodont, Saint Maur-des-Fossés, Cedex, France
Sealapex	Calcium oxide, bismuth trioxide, zinc oxide, sub-micron silica, titanium dioxide, zinc stearate, tricalcium phosphate, blend, ethyl toluene sulfonamide, poly (methylene methyl salicylate) resin, isobutyl salicylate, pigment.	SybronEndo, Orange, CA, USA
Sealer 26	Calcium hydroxide, bismuth oxide, tetramine hexamethylene, titanium dioxide, bisphenol epoxy resin.	Dentsply, Rio de Janeiro, RJ, Brazil
Activ GP Sealer	Poly(acrylic acid), tartaric acid, barium aluminosilicate glass powder, dried poly(acrylic acid).	Brasseler Inc., USA, Savannah, GA, USA
Intrafill	Zinc oxide, hydrogenated colophony, colophony, bismuth subcarbonate, barium sulphate, anhydrous disodium borate, eugenol.	SSWhite, Rio de Janeiro, RJ, Brazil

at 50 kV, 10 mA, 18 pulses s^{-1} and focus-film distance of 33.5 cm was used. Radiographs were digitized using a desktop scanner (SnapScan 1236 – Agfa, Germany) and the digitized images were imported into the VIXWIN 2000 software (Gendex, Desplaines, IL, USA), where an equal-density tool was used to identify equal-density areas in the radiographic images. This procedure allowed comparison between the radiographic density of the sealers and the radiopacity of different thicknesses of the aluminum step-wedge. Double-clicking the left mouse button, the area corresponding to the specimen was selected from each radiographic image, in order to verify which thickness of the aluminum step-wedge was detected by the software as equivalent to the specimen's radiographic density. This assessment determined the radiopacity of the selected material compared to a particular thickness of aluminum, measured in millimeter. Results were analyzed by calculating the means of five measurements *per* sample (one point in the central area and four points in the different quadrants). Data were submitted to statistical analysis using one-way analysis of variance (ANOVA) and Tukey *post hoc* test ($\alpha = 0.05$).

Results

Analysis of variance showed a statistically significant difference between the radiopacity means of the tested sealers. Means, standard deviations and the results of Tukey tests ($\alpha = 0.05$) are presented in Fig. 1.

Intrafill, Sealapex, Sealer 26 and Acroseal had mean radiopacity values greater than the minimum level recommended by the ISO standard while Activ GP Sealer was below the minimum level of 3 mm of alumimium (Fig. 1). Intrafill (7.67 mm Al) was significantly ($P < 0.05$) more radiopaque than all other sealers. Sealer 26 (6.33 mm Al) and Sealapex (6.05 mm Al) had similar radiopacity ($P > 0.05$) and were significantly more radiopaque than Acroseal (4.03 mm Al) and Activ GP sealer ($P < 0.05$). Activ GP Sealer (1.95 mm Al) had the lowest radiopacity means ($P < 0.05$).

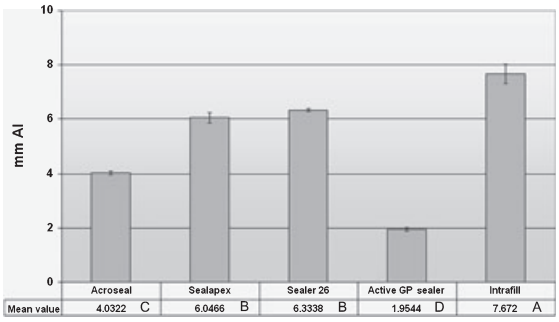

Figure 1 Radiopacity means and standard deviation of the tested materials and results of Tukey *post hoc* test ($\alpha = 0.05$). Means followed by the same letter were not significantly tested ($P > 0.05$).

Discussion

The use of digitized images and computer-aided radiographic image analysis with computer programs especially designed for this purpose has allowed the development of radiopacity studies that are simple executed, reproducible and able to provide reliable results (Tagger & Katz 2003, Tagger & Katz 2004, Tanomaru-Filho *et al.* 2007).

Katz *et al.* (1990) evaluated the radiopacity of guttapercha points and observed that the average radiopacity of the points was approximately the same as that of 7.4 mm of aluminum. McComb & Smith (1976) evaluated, among other physical properties, the radiopacity of nine brands of root canal sealers in comparison with two polycarboxylate-based experimental endodontic materials. The authors concluded that a reduction of radiopaque substance in the sealers decreased their radiopacity. Several other studies have evaluated the radiopacity of composite resin materials using an aluminum step-wedge as a comparison standard (Curtis *et al.* 1990, Gürdal & Akdeniz 1998, Hara *et al.* 2001). Tagger & Katz (2003) developed a technique for assessing the radiopacity of endodontic sealers, using standardized samples radiographed alongside an aluminum step-wedge. The radiographs were digitized and specimen radiopacity was compared with that of the aluminum step-wedge, using computer software. A similar method was used in the present study.

The International Organization for Standardization ISO 6876 (2001) standard establishes that root canal sealers should be at least as radiopaque as 3 mm of aluminum (Katz *et al.* 1990). According to the ANSI/American Dental Association (2000) specification No. 57, endodontic filling materials should present a difference in radiopacity equivalent to at least 2 mm of aluminum in comparison with bone or dentine. Therefore, all sealers evaluated in the present investigation had radiopacity values above the minimum recommended by the ISO standard, except for the glass-ionomer-based sealer (Activ GP).

In this study, Intrafill and Sealer 26 had greater radiopacity than the other sealers. Intrafill contains zinc oxide, bismuth subcarbonate and barium sulphate, which contributes to its greater radiopacity. Sealer 26 contains bismuth oxide, acting as the radiopacifier (Tanomaru *et al.* 2004).

Sealapex and Acroseal had similar radiopacity. The new formulation of Sealapex had greater radiopacity than the previous formulation (Tanomaru *et al.* 2004) due to the addition of bismuth trioxide to its composition. Acroseal was less radiopaque than Sealapex and its radiopacity is related to the presence of bismuth subcarbonate in its formulation. Activ GP sealer was the least radiopaque endodontic sealer (1.95 mm Al). This material does not contain any specific radiopacifier. The presence of barium aluminosilicate glass powder does not provide satisfactory radiopacity. The results of this sealer are consistent with those of previous studies undertaken with restorative glass-ionomer cements (Turgut *et al.* 2003).

The root canal sealers evaluated in this study had different radiopacities. However, except for the glass-ionomer-based sealer (Activ GP Sealer), all materials had radiopacity values above the minimum recommended by the ISO standard.

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