

Evaluation of the radiopacity of root-end filling materials by digitization of radiographic images

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Received for publication: July 25, 2005

Accepted: May 16, 2006

Abstract

The aim of this study was to evaluate the radiopacity of five root-end filling materials (Sealer 26, Zinc Oxide-Eugenol, Sealapex with zinc oxide, Pro Root™ MTA, and MTA-Angelus). Specimens measuring 10 millimeters in diameter and 1 millimeter in thickness were fabricated and radiographed next to an aluminum stepwedge with variable thickness. Radiographs were digitized and radiopacity values of the materials were compared to those of the aluminum stepwedge. The VIXWIN 2000 software was used to determine the radiopacity in millimeters of aluminum (mm Al). Radiopacity values varied from 2.5 mm Al to 8.9 mm Al. Sealer 26 and ZOE were the most radiopaque ($p < 0.05$), while MTA-based materials presented the least radiopacity; Sealapex with zinc oxide presented intermediate radiopacity. The root-end filling materials presented different radiopacity values; MTA-based materials were the least radiopaque, with radiopacity values next to the minimum recommended.

Key Words:

retrograde obturation, root canal filling material, radiology

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Introduction

Retrograde filling is an endodontic surgical procedure frequently used to seal the root canal following root-end resection (apicoectomy)¹⁻². The root-end filling material should present enough radiopacity to allow distinction from adjacent anatomical structures³⁻⁵, such as bone and teeth.

In recent years, materials used in root-end fillings have greatly evolved. Silver amalgam, previously used, is not recommended due to clinical failure⁶, poor marginal adaptation, and inadequate sealing⁷. Other materials currently in use include root canal sealers, either resin-based⁸⁻⁹ or calcium hydroxide-based materials such as Sealapex, with added zinc oxide for better consistency¹⁰.

Mineral Trioxide Aggregate (MTA)-based materials are also frequently used¹¹⁻¹². These sealers are less radiopaque². MTA-Angelus (Angelus, Londrina, Paraná, Brazil) is produced from Portland cement, with bismuth oxide added to increase radiopacity. Its properties, in terms of increasing pH and releasing calcium ions, are similar to Pro Root™ MTA (Dentsply Tulsa Dental, Tulsa, OK), as previously demonstrated by Duarte et al.¹³. Torabinejad et al.¹⁴ studying the properties of MTA in comparison to Super-EBA, IRM and amalgam demonstrated that MTA is more radiopaque than Super-EBA and IRM.

Eliasson and Haaskel¹⁵ (1979) have established a comparison standard for radiopacity studies, using optical density values for impression materials and calculating the equivalent thickness of aluminum required to result in similar radiographic density. Tagger and Katz¹⁶ developed a method to measure radiopacity that includes obtaining radiographic images of materials next to an aluminum stepwedge. This method also involves digitization of the radiographic images and utilization of specific software to determine the gray pixel values.

In another study, Tagger and Katz⁷ (2004) emphasized that international norms are needed to standardize the minimum radiopacity for retrograde filling materials, due to the great variability observed among materials currently in use.

The objective of the present study was to evaluate the radiopacity of five root-end filling materials, by the comparison of the materials samples to the radiopacity of an aluminum stepwedge, according to ISO Standard 6876:2001¹⁷.

Material and Methods

Five root-end filling materials were evaluated in this study: Sealer 26 (Dentsply, Petrópolis, RJ, Brazil), Zinc Oxide–Eugenol (S.S.White, Rio de Janeiro, RJ, Brazil), Sealapex (Kerr Corp., Orange, CA, USA) with zinc oxide (Kerr Corp., Orange, CA, USA), Pro Root™ MTA (Dentsply Tulsa dental, Tulsa, OK, USA), and MTA (Angelus, Londrina, PR, Brazil). Sealer 26 is a resin-based root canal sealer; when Sealer 26 is used as a root-end filling, it is manipulated in thicker consistency. Sealer 26 was manipulated in the proportion of 5:1 powder:

resin weight¹⁸ and Sealapex plus zinc oxide in the proportion of 1:1:2 base paste:catalyzer:zinc oxide weight¹⁰. Pro Root MTA was manipulated according to manufacturer instructions. The MTA-based materials were handled according to manufacturers' instructions. Five specimens, 10 millimeters in diameter and 1 millimeter thick, were fabricated from each material tested. Metallic matrices were made and impressions were taken using a silicone-based impression material. Samples of the prepared filling materials were then inserted into the impressions and stored in a moist chamber (incubator) at 37° C, until completely set.

Following that, the specimens were placed onto five occlusal radiographic films (Insight – Kodak Comp, Rochester, NY, USA) and exposed, next to a graduated aluminum step wedge with variable thickness (from 2 to 16 mm, in 2 mm-increments). A GE-1000 radiographic unit (General Electric, Milwaukee, WI, USA) operating at 50 kilovolts, 10 milliamperes, 18 pulses per second, and focus-film distance of 33.5 cm, was used for taking the radiographs. The radiographic images were digitized using a desktop scanner (SnapScan 1236 – Agfa, Deutschland), and the digitized images were imported into the VIXWIN 2000 software (Gendex, Desplaines, IL, USA). The equal-density tool was used to identify equal-density areas, allowing comparison between the different materials' densities and the radiopacity of the different degrees of thickness in the aluminum step wedge. Using the computer mouse, the area corresponding to the specimen was selected from each radiographic image, in order to determine which thickness of the aluminum step wedge was detected by the software as presenting the same radiographic density as the sample. The optical density values may vary from 0 to 255, according to the WIXWIN software. After determining the optical density value for each specimen, the following formula was applied in order to convert the values into millimeters of aluminum:

Al equivalent (mm) = radiopacity of the specimen X Al thickness of the aluminum stepwedge (mm) / radiopacity of the stepwedge

This formula determined the equivalence of each material's radiopacity to a particular thickness of aluminum, measured in millimeters. Results were analyzed by calculating the arithmetic mean of five measurements per specimen. Data were submitted to statistical analysis using ANOVA and Tukey test.

Results

The results of radiopacities values are presented in Table 1. The statistical analysis using ANOVA and Tukey test showed that Sealer 26 and ZOE presented the greatest radiopacity ($p < 0.05$), equivalent to 8.9 mm Al (Figure 1). Sealapex plus zinc oxide presented radiopacity equivalent to 6.3 mm Al. The Mineral Trioxide Aggregate-based materials were the least radiopaque ($p < 0.05$), varying from 2.5 (Pro Root MTA – Figure 2) to 3.7 mm Al (MTA Angelus).

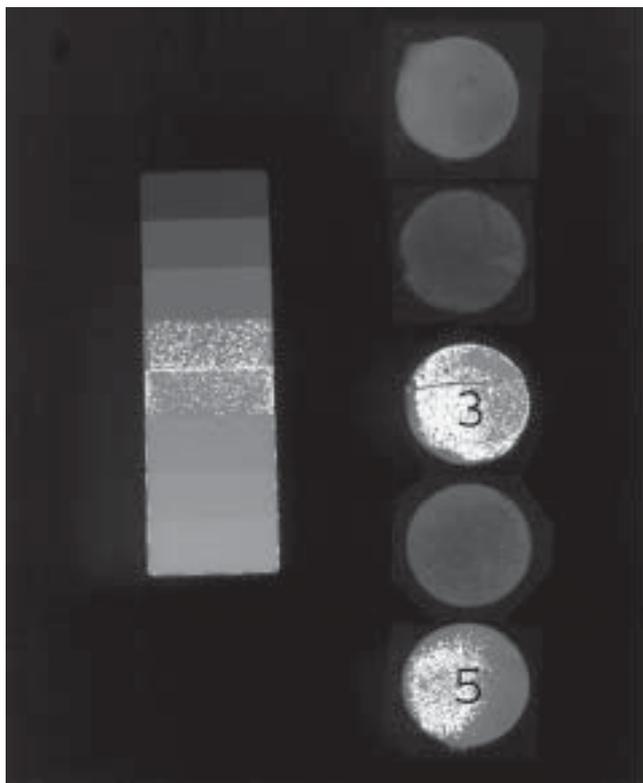


Fig. 1 – Radiograph showing the radiopacity of Sealer 26 (3) and OZE (5) and the equivalence to the aluminum stepwedge.

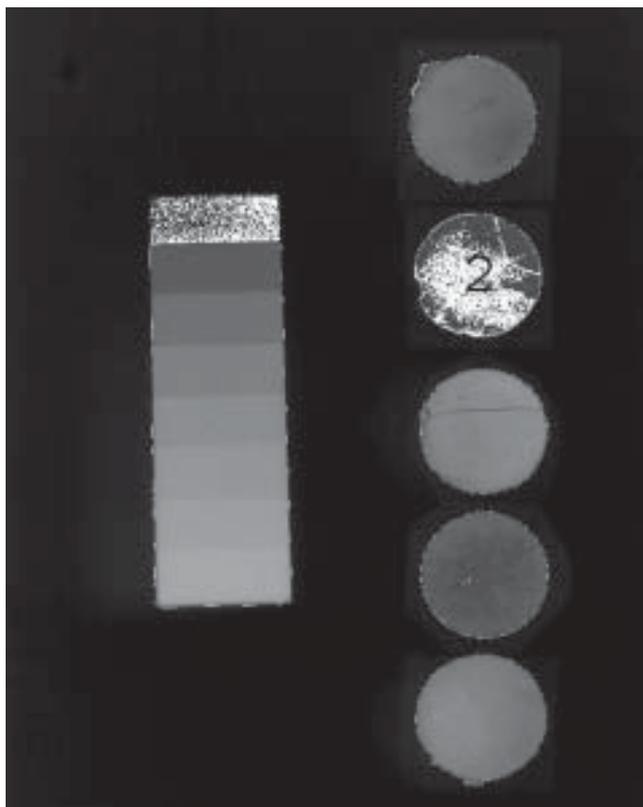


Fig. 2 – Radiograph showing the radiopacity of Pro Root™ MTA (2) and its equivalence to the aluminum stepwedge.

Table 1 – Materials evaluated and their mean radiopacity values (mm Al).

Root-end filling material	Mean radiopacity (mm Al)	Std. Deviation
Sealer 26	8.9	0.74
Zinc Oxide-Eugenol	8.9	0.8
Sealapex plus zinc oxide	6.3	0.33
Pro Root™ MTA	2.5	0.18
MTA Angelus	3.7	0.11

Discussion

Several radiopacity studies have included comparison to an aluminum stepwedge with varying thickness. Katz et al.¹⁹ compared the radiopacity of gutta-percha cones to an aluminum stepwedge, and observed an average radiopacity of 7.4 mm Al. Other studies evaluated the radiopacity of composite resin-based materials, also using an aluminum stepwedge as a standard for comparison²⁰⁻²¹. Tanomaru et al.²² evaluated the radiopacity of root canal sealers using similar methodology.

Beyer-Olsen and Orstavik³ determined the radiopacity of several root canal sealers using an aluminum stepwedge with 2mm-increments. Their studies demonstrated that most materials analyzed were more radiopaque than dentin.

Shah et al.⁵ state that root-end filling materials should be distinguishable from the adjacent bone and radicular dentin, and that materials with radiopacity values smaller than 3 mm Al are indistinguishable. According to the same authors, an international standardization establishing the minimum acceptable radiopacity of root-end filling materials is urgently needed.

Shah et al.⁵ and Laghios et al.²³ evaluated the radiopacity of several root-end filling materials. The authors reported that most of these materials present radiopacity greater than 2mm Al, except for glass ionomer-based cements.

The ISO Standard 6876:2001¹⁷ establishes 3 mm Al as the minimum radiopacity for root canal sealers. According to ANSI/ADA's specification number 57²⁴, root canal sealers should be at least 2mm Al more radiopaque than bone or dentin.

The results in the present study demonstrated that Sealer 26 and ZOE present optimal radiopacity, equivalent to 8.9 mm Al. Sealer 26 powder includes bismuth oxide, which is responsible for its radiopacity. On the other hand, zinc oxide confers radiopacity to ZOE and to the association Sealapex plus zinc oxide (6.3 mm Al).

The Mineral Trioxide Aggregate-based materials presented lower radiopacity values. The least radiopaque was Pro Root™ MTA, (2.5 mm Al). MTA-Angelus presented radiopacity equivalent to 3.7 mm Al. Bismuth oxide is added to both materials to provide radiopacity. However, it is not

sufficient to provide adequate radiopacity to the materials. Pro Root™ MTA presented radiopacity equivalent to the minimum according to ANSI/ADA's specification number 57²⁴ for root canal sealers.

According to the analysis of results in the present study, it may be concluded that the evaluated root-end filling materials present different radiopacities. MTA-based materials were the least radiopaque, with radiopacity values next to the minimum recommended for root canal sealers.

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