Radiopacity evaluation of Portland and MTA-based cements by digital radiographic system

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ABSTRACT

Objective: The aim of the present study was to evaluate the radiopacity of Portland and MTA-based cements using the Digora TM digital radiographic system. Material and Methods: The performed tests followed specification number 57 from the American National Standard Institute/American Dental Association (2000) for endodontic sealing materials. The materials were placed in 5 acrylic plates, especially designed for this experiment, along with a graduated aluminum stepwedge varying from 1 to 10 mm in thickness. The set was radiographed at a 30 cm focus-object distance and with 0.2 s exposure time. After the radiographs were taken, the optical laser readings of radiographs were performed by Digora TM system. Five radiographic density readings were performed for each studied material and for each step of the aluminum scale. Results: White ProRoot MTA (155.99±8.04), gray ProRoot MTA (155.96±16.30) and MTA BIO (143.13±16.94) presented higher radiopacity values ($p<0.05$), while white non-structural Portland (119.76±22.34), gray Portland (109.71±4.90) and white structural Portland (99.59±12.88) presented lower radiopacity values ($p<0.05$). Conclusions: It was concluded that MTA-based cements were the only materials presenting radiopacity within the ANSI/ADA specifications.

Key words: Endodontics. Dental radiography. Digital radiography. Radiology. Retrograde obturation. Root canal filling materials.

INTRODUCTION

The role of endodontic sealers is to establish a perfect and hermetic periapical environment seal[18]. Ideally, these materials should be biocompatible with periradicular tissues, non-absorbable, adaptable to dentin walls and should present good handling characteristics and no cytotoxicity[6,19,22,23].

Mineral trioxide aggregate (MTA)-based cements have been widely investigated for endodontic applications[19]. The use of MTA as retrofilling material, in animals, has shown an induction of lower inflammatory response[4]. MTA has been also employed for pulp capping[20], in root perforations reparation[18] and as barrier for teeth with open apexes[13].

Although MTA is known for its superiority compared to other retrofilling materials, it is more expensive, limiting its use. Biocompatibility studies comparing MTA and Portland cements have shown similar results[22]. Most components are similar for both materials[10]. Bismuth oxide, which is responsible for radiopacity, is present in MTA, but not in Portland cement[10,12]. This material is classified as structural or non-structural cement. Structural cement presents high quantities of carbonatic material in its composition, being responsible for material resistance[2].

The ideal filling material should present sufficient radiopacity to be distinguished from dental structures and be evaluated inside the cavity[24]. Studies evaluating radiopacity employ an aluminum stepwedge, and more recently, digital methods that determine gray values have been proposed[3], involving radiograph digitization and the use of specific software to determine the pixel gray values[25]. In this process, these values are converted into millimeters of aluminium equivalent and related to radiopacity of materials[5]. Using a digital radiography system, this study evaluated the radiopacity of Portland and MTA-based cements according to the American National Standard Institute/American Dental Association's specification #57 for endodontic sealing materials[1].

MATERIAL AND METHODS

Five acrylic plates (2.2 cm x 4.5 cm x 1 mm) with 6 holes measuring 1 mm in depth and 5 mm of internal diameter were fabricated[5]. The acrylic plates were placed onto a glass plate covered by cellophane paper and each orifice was filled with one of the tested cements (Figure 1).

For the radiographic exposure, each acrylic plate containing the cements was positioned together with another acrylic plate (1.3 cm x 4.5 cm x 1 mm), which contained a graduated aluminum stepwedge varying from 1 to 10 mm in thickness, and uniform steps of 1 mm each[1].

The set of plates was built with standardized measurements in a way that they would correspond exactly to the sensor size (phosphor plate), from Digora TM system (Soredex, Orion Corporation, Helsink, Finland), used for data collection. A 70 kVp and 8 mA radiograph machine, Spectro 70X (Dabi Atlante, Dabi Atlante Indústrias Médico Odontológicas Ltda, Ribeirão Preto, SP, Brazil), was used. The focus-object distance was 30 cm (ANSI/ADA 2000) and exposure time at 0.2 s, as instructed for digital radiography of phosphor plates, by the manufacturer (Figure 2).

An acrylic positioning device with metallic fastener held sensors and provided an adequate and standardized focus-object distance. The radiograph machine head was fixed on the same position with central beam presenting 90° angle of incidence with the acrylic/sensor surface plates set. A rectangular collimator (Dabi Atlante, Dabi Atlante Indústrias Médico Odontológicas Ltda) presenting 3x4 cm aperture reduced possible secondary radiation by being attached to the end of cylinder.

The sensor, after being exposed, was inserted into the laser optical reader of Digora™ for Windows 5.1 software. As soon as the first image was revealed on screen, parameters suggested by the system were established, allowing to image standardization. The same phosphor plate was used for all exposures to avoid possible differences between plates.

The system performed a radiographic density reading over images of each cement revealed on screen, and also a reading of steps on an aluminum stepwedge, resulting in a numeric value for each reading. This value was written down by the evaluator. After evaluating the 5 acrylic set of plates, 5 measurements for each type of cement and for each step of the aluminum scale were obtained. Mean values of radiographic density and graduated aluminum stepwedge were determined for each material. Mean values were taken by a single evaluator previously trained and blinded with regard to the different groups. Intergroup relation analysis was tested using one-way ANOVA (α=0.05). Pairwise multiple comparisons were carried out using the Bonferroni test (α=0.05) in the cases where the ANOVA test showed significant differences.

RESULTS

The mean radiographic density values of the cements, in mm Al, are presented in Table 1. MTA-based cements (MTA BIO, gray and white ProRoot MTA) presented the highest radiopacity values

Root canal sealer	Composition*	Manufacturer
White structural Portland	White clinker (100-75%), Gypsum (3%) and Carbonate Material (0-25%)	Votorantim Cimentos Brasil S/A, Votorantim, SP, Brazil
Gray Portland	Gray clinker (97%) and Gypsum (3%)	Votorantim Cimentos Brasil S/A, Votorantim, SP, Brazil
White non-structural Portland	White clinker (74-50%), Gypsum (3%) and Carbonate Material (26-50%)	Votorantim Cimentos Brasil S/A, Votorantim, SP, Brazil
MTA BIO	Portland Cement (80%) and Bismuth oxide (20%)	Angelus Ind. Prod., Londrina, PR, Brazil
Gray ProRoot MTA	Portland Cement (75%), Bismuth oxide (20%) and Gypsum (5%)	Dentsply-Tulsa Dental, Tulsa, OK, USA
White ProRoot MTA	Portland Cement (75%), Bismuth oxide (20%) and Gypsum (5%)	Dentsply-Tulsa Dental, Tulsa, OK, USA

*information according to the manufacturers

Figure 1- Tested materials and compositions

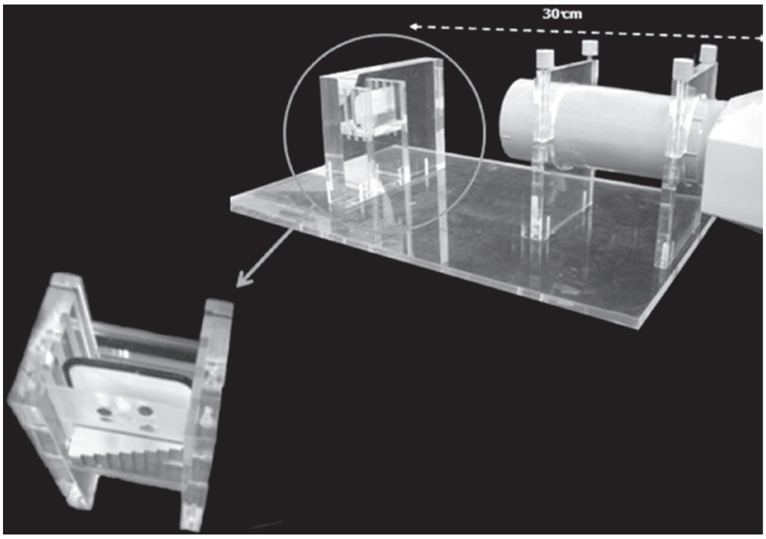

Figure 2- Experimental set-up used to fix x-ray machine central beam and the acrylic plates/phosphor plate set at a focus-object distance of 30 cm. In greater magnification, experimental set-up with the aluminium stepwedge, wells for root canal filling materials and radiography digital phosphor plate

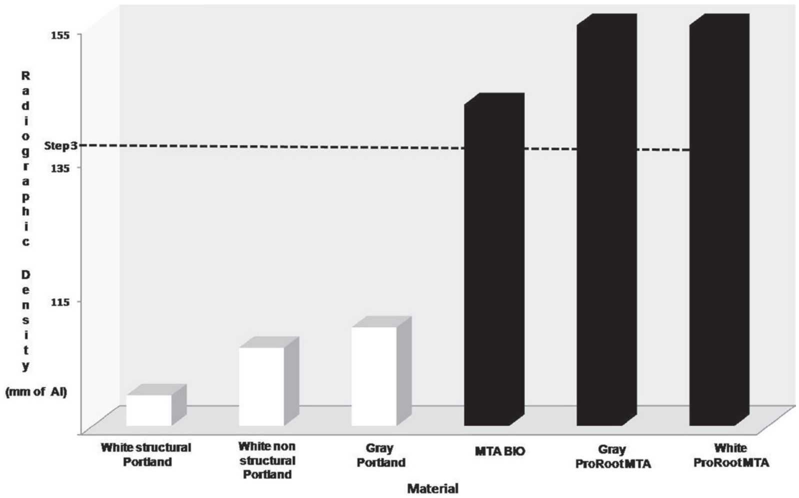

Figure 3- Radiopacity of cements in comparison with steps of the aluminium scale. The black color relates to cements whose radiopacity density (mm Al) fulfills the ANSI-ADA specification number 57 (step 3). The white color refers to cements with radiopacity lower than the value recommended by the ANSI-ADA

Table 1- Radiographic density of the cements (mean ± standard deviation)

Root canal sealer	Radiographic density (mm Al)
White structural Portland	99.59±12.88[a]
Gray Portland	109.71±4.90[a]
White non-structural Portland	119.76±22.34[a]
MTA BIO	143.13±16.94[b]
Gray ProRoot MTA	155.96±16.30[b]
White ProRoot MTA	155.99±8.04[b]

Radiopacity means ± standard deviation of the tested materials and results of ANOVA and Bonferroni test (α=0.05). Different letters indicate statistically significant differences at 5% significance level.

among the tested materials ($p<0.05$), overcoming 3 steps from the aluminum stepwedge, which is the minimum radiopacity recommended by the ANSI/ADA specification number 57[1] (Figure 3).

No statistically differences were observed between each other. Portland cements (gray, white structural and white non-structural) presented the lowest radiopacity values ($p<0.05$), not reaching the ANSI/ADA[1] (2000) recommendation.

DISCUSSION

Up to present moment, there are no specific standards for retrofilling materials to support and reference studies on their physico-chemical properties. Published studies followed standards proposed by the ANSI/ADA specification number

57[1] for endodontic sealing materials[11,27], and the ISO 6876 standard for zinc oxide and eugenol endodontic sealing materials[6,15]. This equivalence is based on the fact that, under clinical conditions, retrofilling materials and root filling materials remain in direct contact with periodontal and periapical tissues[8,18].

Both ISO and ANSI/ADA have adopted equivalence procedures with an aluminium scale steps, in order to analyze several dental materials radiopacity[3]. It is known that the radiopacity of 1 mm of dentin is equivalent to 1 mm of aluminum in a graduated stepwedge[9]. According to the ANSI/ADA specification number 57[1], an endodontic sealing material should present radiopacity correspondent to at least 3 mm Al.

Digital measurement methods have been proposed by determining gray-tones values, measured in pixels[21]. These systems can differentiate all shades of gray on a digital image, while the naked human eye cannot identify 255 shades, on a non-digitized film[5]. Some studies used direct methods of analysis[5], while others preferred indirect methods, through scanning images obtained by occlusal films[25,26]. Besides, digital x-ray films provide reduction in processing time and in number of steps that could interfere on final radiograph quality[21].

Retrofilling materials should present enough radiopacity to be radiographically distinguished from surrounding structures, such as tooth and alveolar bone, and to reveal empty spaces and inappropriate contours[17]. Only gray and white ProRoot MTA cements and MTA BIO, among the studied materials, met the ANSI/ADA recommendations. This fact was expected since ProRoot MTA and MTA BIO are reinforced with 20% bismuth oxide in their composition[7,10]. However, other studies reported a lower quantity of bismuth oxide on MTA BIO composition, justifying its lower radiopacity in comparison to ProRoot MTA, corroborating with this study's findings[6,8,16].

The original formulation of Portland cement did not present bismuth oxide[10], determining its low radiopacity and making impossible to distinguish it from bone tissue[14]. Mean values obtained for this cement were lower than 2 mm Al, not reaching the minimum requirements of the ANSI/ADA[1] (2000). The inadequate radiopacity of Portland cement has been reported[8]. In order to address this issue, radiopacity was studied when Portland cement was associated to different radiopacifiers[14]. Results demonstrated that incorporation of a radiopacifier agent promotes satisfactory radiopacity, being also higher than dentin radiopacity[14]. However, it should be further investigated if the cement/radiopacifier agent mixture does not interfere with the original physicochemical properties and biocompatibility of Portland cements.

CONCLUSIONS

Based on the employed methodology and obtained results, it can be concluded that only MTA-based cements met the ANSI/ADA specification number 57[1] with respect to radiopacity.

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