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ORIGINAL RESEARCH

Radiopacity of Mineral Trioxide Aggregate with and without Inclusion of Silver Nanoparticles

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ABSTRACT

Aim: The aim of this study was to investigate the inclusion of silver nanoparticles (Ag NPs) in the mineral trioxide aggregate (MTA) composition to know which changes will result in the radiopacity of the material.

Materials and methods: The experiment was performed according to the American National Standard Institute/American Dental Association specification no. 57/2000 and ISO 6876/2001. Five plates with five holes measuring 1 mm in depth and 5 mm in internal diameter were filled according to the different experimental groups as follows: white mineral trioxide aggregate (WMTA) + NP50 – W MTA with liquid Ag NP 50 ppm, WMTA + NP30 – W MTA with liquid Ag NP 30 ppm, WMTA + NP22 – W MTA with liquid Ag NP 22 ppm, WMTA + NPP – white MTA with liquid Ag NP and powder 1%, WMTA (control). After filling the plates, they were kept in an incubator at 37°C in relative humidity for setting. Each sample was positioned along an aluminum step-wedge placed above the Opteo digital sensor system. The image was divided into four quadrants, and three readings were made for each quadrant to render the average of each quadrant. The resulting data were submitted to Kruskal–Wallis and Dunn's tests.

Results: The results showed statistically significant differences between WMTA + NP30, WMTA + NP22, and WMTA + NPP interactions compared with WMTA (control) ($p < 0.05$). The radiopacity was in descending order: WMTA + NPP, WMTA + NP22, WMTA + NP30, MTA + NP50, and WMTA.

Conclusion: Silver NPs changed the radiopacity of WMTA, being more evident in WMTA + NP powder at 1% weight.

Clinical significance: The low radiopacity of MTA makes it difficult for any radiographic observation. The Ag NPs appear as an alternative, being an excellent radiopacifier as they have excellent antimicrobial property and relatively low toxicity.

Keywords: Endodontics, Mineral trioxide aggregate, Nanoparticles, Physical properties.

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INTRODUCTION

The mineral trioxide aggregate (MTA) is a derivative of Portland cement (PC) and was introduced in dentistry by Torabinejad et al,[1] with its composition being similar to that of cements, except for the presence of the radiopacifier bismuth oxide (Bi_2O_3) contained in the MTA.[2,3] Initially, MTA was strictly used as a filling material for apical surgery.[4-6] It is also currently used for perforation repair, sealing of pathological communication between pulp cavity and periodontal tissue,[7,8] treatment of teeth with incomplete root formation, and pulp capping.[9,10]

Among the MTA properties, radiopacity should be noted as through one can visualize the material on the radiograph, allowing to see both contours and relationship of the material with adjacent tissues. One of the MTA components responsible for its radiopacity is the Bi_2O_3, but it interferes negatively with other properties, such as reducing the release of calcium ions, increasing the solubility, and causing deterioration of the dimensional stability of the material.[11] Furthermore, it also increases the porosity and hence decreases the resistance.[12-15]

The radiopacifying agents have been introduced in an attempt to improve its physical properties, such as iodoform,[16] barium sulfate,[17] and, more recently, silver nanoparticles (Ag NPs).

According to the American National Standard Institute/American Dental Association (ANSI/ADA) specification no. 57/2000 and ISO 6876/2001, the radiopacity of the endodontic materials must be ≥3 mm of aluminum equivalent, which is found in the MTA.[18-20]

The addition of substances to sealers can change the radiopacity.[17] Bortoluzzi et al[17] added bismuth oxide (Bi_2O_3), barium sulfate ($BaSO_4$), iodoform (CHI_3), and zirconium oxide (ZrO_2) to white (MTA WMTA) and PC cements. The higher radiopacity occurred in the interaction involving PC + Bi_2O_3 (5.88 mm of Al), followed by pure WMTA (5.72 mm of Al), PC + ZrO_2 (3.87 mm of Al), and PC + CHI_3 (3.50 mm of Al). Some samples were below the recommended ISO, such as PC + $BaSO_4$ (2.35 mm of Al) and pure PC (1.69 mm of Al).

Nanotechnology enables preventing and combating diseases by using nanoscale materials. Some authors observed that NPs improve both fluidity and workability as they influence the process of hydration and fill the empty spaces.[21,22] In addition, NPs provide these effects even when used at low levels.[23]

The Ag NPs show high antibacterial efficacy and low toxicity to humans,[24,25] being studied in various dental applications, such as restorative material,[26] retrosealer,[27] and dental implants.[28]

Within this context, the inclusion of Ag NPs into MTA compositions should be investigated to know the changes in the radiopacity. Thus, the purpose of this study was to evaluate the radiopacity of pure MTA and with the addition of Ag NPs.

MATERIALS AND METHODS

The radiopacity was evaluated according to the specification no. 57 of the ANSI/ADA (2000) and ISO 6876/2001 standards for root canal sealing materials.

Five acrylic plates containing five orifices measuring 1 mm in depth and 10 mm in inner diameter were filled according to the material used in the different experimental groups, and then they were divided into four quadrants for sample reading (n = 20) (Table 1).

The WMTA was handled according to the manufacturer's recommendations. The MTA powder was placed on a dosing spoon and weighed on a precision scale (Ohaus Corporation Pine Brook, New Jersey, USA), with a content of 0.12 gm of MTA powder. Nanoparticles in powder form were added to the MTA powder at a ratio of 1% by weight of powder (0.0012 gm). The NP liquid was replaced in the MTA liquid container.

The sample was removed from the plate and positioned at the time of radiographic exposure and positioned along an aluminum step-wedge over the Opteo digital sensor system. The aluminum step-wedge was made of alloy 1100 aluminum with a thickness ranging from 1 to 10 mm in uniform steps of 1 mm each (ANSI/ADA 2000). The set containing both the sample and the aluminum step-wedge was placed on the phosphor plate of the Opteo system (Owandy radiology, Croissy-Beaubourg, France) and positioned at 30 cm from the X-ray unit (Spectro 70X, DabiAtlante, Ribeirão Preto, São Paulo, Brazil) operating at 70 kVp, 8 mA and activation time of 0.48 seconds.

For the reading of the image, the sample was divided into four quadrants, and three radiographic density measurements for each of the quadrants were used as average of the three readings. The radiographic densities of the digital images were evaluated by an independent examiner and then calibrated by using the histogram tool of the Adobe Photoshop 8.0. Thus, we obtained the shades of gray to the aluminum scale and samples. An average of these measurements was calculated to render four readings for each sample. Similarly, this measurement was also held at the aluminum step-wedge. Each quadrant of each sample of the cements was studied by comparing it with the aluminum step-wedge, which had the same radiopacity. The measurement density was transformed into Al mm. The resulting data were submitted to Kruskal–Wallis and Dunn's tests at $p < 0.05$.

RESULTS

In Table 2, one can observe the data obtained by reading the samples of different experimental groups. The results showed that the inclusion of Ag NPs promoted a slightly better radiopacity, whereas the highest levels were found in the WMTA + NPP interaction, followed by WMTA + NP22, WMTA + NP30, WMTA + NP50, and WMTA (control) (Graph 1 and Fig. 1).

The results showed statistically significant differences only in the following interactions: WMTA + NP30, WMTA + NP22, and WMTA + NPP compared with the control group (WMTA) ($p < 0.05$). The other interactions did not show statistically significant differences.

Table 1: Division of the experimental groups

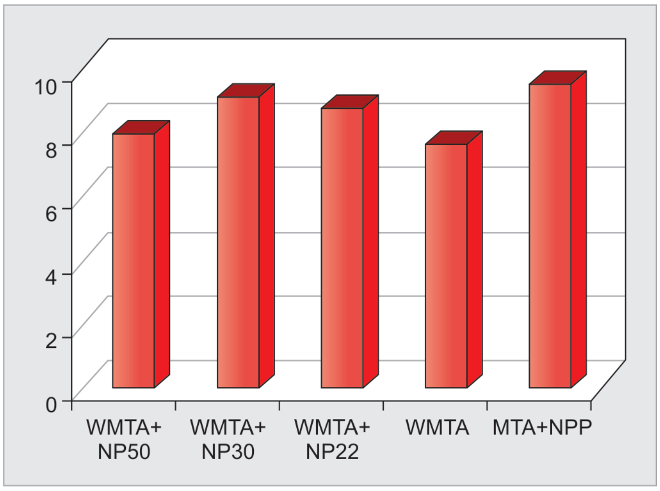
Groups	*Material*
WMTA + NP50	WMTA[1] with liquid Ag NP 50 ppm[2]
WMTA + NP30	WMTA[1] with liquid Ag NP 30 ppm[2]
WMTA + NP22	WMTA[1] with liquid Ag NP 22 ppm[2]
WMTA + NPP	WMTA[1] with liquid Ag NP and NP powder 1% (>100 nm)[3]
WMTA (Control)	WMTA[1]

[1]Origin: Angelus Indústria de Produtos Odontológicos S/A, Paraná, Brazil; [2]Origin: Khemia, IPEN, Brazil; [3]Origin: Sigma-Aldrich Brazil Ltd, São Paulo, Brazil

Table 2: Data obtained (mean ± SD) of radiopacity in the different experimental groups

	Material				
	WMTA + NP50	*WMTA + NP30*	*WMTA + NP22*	*WMTA*	*MTA + NPP*
Mean ± SD	7.91 ± 0.9962	9.0 ± 0.8528	8.66 ± 1.3027	7.58 ± 0.5129	9.50 ± 0.5222

SD: Standard deviation



Graph 1: Data obtained from radiopacity in the different experimental groups

DISCUSSION

The sealers should have adequate radiopacity so that one can visualize the filling material and its relationship with the root canal and adjacent structures. To meet this requirement, various radiopacifiers have been used, such as barium sulfate, iodoform, and zirconium oxide[17] as well as gold, silver alloy tin, niobium oxide, and zirconium oxide.[19]

Both ISO and ANSI/ADA adopt the aluminum step-wedge to analyze the radiopacity. It is known that dentin of 1 mm thickness is equivalent to an 1 mm aluminum scale, meaning that the material should have a radiopacity of at least 3 mm Al.[13,18-20] Although these specifications are actually for sealers, they are an equivalence based on the fact that both materials will be in contact with periodontal and periapical tissues under clinical conditions.[18]

The aluminum step-wedge is widely used to measure the radiopacity of the material and its measurement made through digital software minimizes potential errors due to visual acuity.[10,14,15,18]

The use of nanotechnology in this study was based on the reality in all areas of knowledge, with positive results in our experiments.[29] In dentistry, NPs have demonstrated to improve antibacterial and osteoinductive properties. According to Viapiana et al,[29] who used ZrO_2 and niobium, the incorporation of NP improved biological properties.

In the literature, there are few studies on the physical properties of the MTA material with inclusion of Ag NPs, hence the importance of further studies that can contribute to the current knowledge stage.

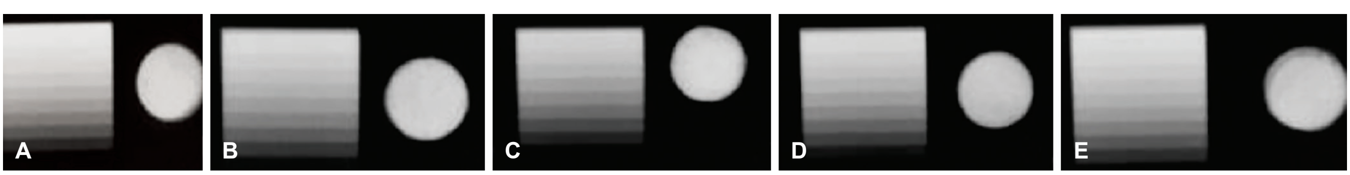
It is known that the MTA cement meets the ADA's recommendations for radiopacity since 20% bismuth oxide is included in its composition.[10,14,15,18] In this study, the group having the highest radiopacity values was one in which Ag NPs in powder form (9.5 mm Al) were added, followed by the groups with net NP at 30 ppm (9.0 mm Al), 22 ppm (8.66 mm Al), 50 ppm (7.91 mm Al) and by the group without NP (7.58 mm Al). These data should be considered because all groups using silver NP had better results than that using pure MTA (control).

When compared with each other, the interactions 30 ppm × pure MTA, 22 ppm × pure MTA, and NP powder × pure MTA showed statistically significant differences. These results are different from those found by Viapiana et al,[29] who added zirconium oxide and niobium oxide to PC and achieved lower results than 3 mm Al (2:42 and 2:31 ratios respectively). Probably these differences occurred because different materials were used at different proportions.

However, our results are promising and further experiments are necessary to better understand the physical properties of the MTA for different groups of Ag NPs.

CONCLUSION

According to the present methodology and results, it could be concluded that Ag NPs changed the radiopacity of MTA, but all were above 3 mm Al. The radiopacity in descending order was: WMTA + NPP, WMTA + NP30, NP22 + WMTA, WMTA + NP50, and WMTA (control).



Figs 1A to E: Radiopacity in the different experimental groups: (A) WMTA + NPP; (B) WMTA + NP22 ppm; (C) WMTA + NP30 mm; (D) WMTA + NP50 mm; and (E) WMTA (control)

CLINICAL SIGNIFICANCE

The low radiopacity of MTA makes it difficult for any radiographic observation. Studies show that the presence of Bi_2O_3 radiopacifier reduces the release of calcium hydroxide, with its solubility increasing and causing deterioration in the dimensional stability of the material. The Ag NPs appear as an alternative, being an excellent radiopacifier as they have excellent antimicrobial property and relatively low toxicity. Therefore, further studies should be performed in order to make its use feasible as an alternative to MTA and to control endodontic infection.

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