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Araştırma / Original Paper

Evaluation of The Radiopacity of a MTA-Based Root-Canal Filling Material using Digital Radiography

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ÖZET

MTA-esaslı bir kök-kanal dolgu materyalinin radyo-opasitesinin dijital radyografi kullanılarak değerlendirilmesi

Amaç: Bu çalışmanın amacı son zamanlarda kullanıma giren mineral trioksit agregat (MTA) esaslı bir kök-kanal dolgu materyali olan MTA Fillapex'in radyo-opasitesinin dört farklı kök-kanal dolgu materyali ile dijital görüntüleme yöntemi kullanılarak karşılaştırılmasıdır.
Yöntemler: Çalışmada kök-kanal dolgu maddesi olarak MTA Fillapex, Adseal, AH Plus, Endomethasone ve güta-perka kon kullanılmıştır. Her bir kök-kanal dolgu materyalinden hazırlanan disk şeklindeki standart numuneler ve alüminyum penetrometre fosfor plaka (size 4; 5.7x7.6 cm) üzerine konarak 70 kVp, 8 mA ve 0.2 sn ışınlama parametreleri ile dijital radyografileri elde edilmiştir. Obje-ışın mesafesi 30 cm olacak şekilde ayarlanmıştır. Test edilen materyallerin grilik değerleri sistemin kendi yazılımı ile dijital olarak ölçülmüş ve eşdeğer alüminyum kalınlığını bulmak amacıyla penetrometre ile karşılaştırılmıştır. Elde edilen bulgular istatistiksel olarak, anlamlılık p<0.05 düzeyinde değerlendirilmiştir.
Bulgular: Test edilen materyallerin radyo-opasite değerlerinin milimetre cinsinden alüminyum eşdeğerleri büyükten küçüğe doğru AH Plus (9.70), güta-perka (6.82), MTA Fillapex (5.30), Adseal (3.71) ve Endomethasone (3.67) şeklindedir. Kullanılan kanal dolgu materyallerinin ortalama radyografik dansite değerleri arasında istatistiksel olarak anlamlı farklılık tespit edilmiş (p<0.005) olup en yüksek radyografik dansite değerine sahip olan kanal dolgu materyali AH Plus olmuştur.
Sonuç: MTA Fillapex çalışmada test edilen kök-kanal dolgu materyalleri arasında radyo-opasite açısından üçüncü sıradadır. Çalışmada kullanılan tüm materyallerin radyo-opasite değerleri Uluslararası Standartlar Örgütü ve Amerikan Ulusal Standartlar Enstitüsü/Amerikan Dişhekimleri Birliği tarafından tavsiye edilen minimum standart değerlerini karşılamıştır.
Anahtar sözcükler: Alüminyum penetrometre, dijital radyografi, radyo-opasite, kök-kanal dolgu materyali

ABSTRACT

Evaluation of the radiopacity of a MTA-based root-canal filling material using digital radiography

Objective: The aim of this study was to assess the radiopacity of a relatively new mineral trioxide aggregate (MTA)-based root-canal filling material and to compare it with four currently used root-canal filling materials using a digital imaging system.
Methods: The root-canal filling materials tested were MTA Fillapex, Adseal, AH Plus, Endomethasone and gutta-percha cones. Standard disks of five different root-canal filling materials were exposed together with an aluminum stepwedge calibrated in millimeters. For the radiographic exposures, a storage phosphor plate (size 4; 5.7x7.6 cm) and an x-ray machine at 70 kVp and 8 mA were used. The object-to-focus distance was 30 cm, and the exposure time was 0.2 sec. The grey values of the test materials were measured digitally using the system's own software and compared with the stepwedge to find the equivalent thickness of aluminum. The data were analyzed statistically with significance levels set at p<0.05.
Results: The radiopacity values of the studied materials in decreasing order, expressed in millimeters of aluminum equivalent, were: AH Plus (9.70), gutta-percha (6.82), MTA Fillapex (5.30), Adseal (3.71) and Endomethasone (3.67). Statistically significant differences were found between mean radiographic density values of the tested materials (p<0.005), AH Plus showing the highest value.
Conclusion: MTA Fillapex was the third most radiopaque root-canal filling material among the tested materials in the study. All of the materials evaluated met the minimum radiopacity standard recommended by International Organization for Standardization and the American National Standards Institute/American Dental Association.
Key words: Aluminum stepwedge, digital radiography, radiopacity, root-canal filling material

INTRODUCTION

Radiopacity is widely acknowledged as a desirable property for all intraoral dental materials, including root-canal filling materials (1). A root-canal filling material should be distinguished from the neighboring anatomical structures (bone and tooth structures) and other dental materials (resin, amalgam and cements) (2-4); it should also facilitate the evaluation of the quality of the filling which can be performed only through radiographic examination (5). Therefore, an ideal root-canal filling material should present a sufficient radiopacity among other physical/chemical properties.

Higginbotham (6) was the first researcher to assess the radiopacity of various root-canal filling and cone materials used for obturation, while Eliasson and Haasken (7) were the first to establish a comparison standard for radiopacity studies using optical radiographic density values and calculating the equivalent thickness of aluminum capable of producing similar values of radiographic density. This model was adapted by Beyer-Olsen and Ørstavik (3) who measured the amount of light transmitted by the specimen with the aid of an optical densitometer and translated it into equivalent thickness of aluminum by comparing it with an aluminum stepwedge (penetrometer) radiographed on the same film. Their study served as a reference for the International Organization for Standardization (ISO) and the American National Standards Institute/American Dental Association (ANSI/ADA) for determining the minimal requirement of radiopacity for root-canal filling materials.

The ISO standard (8) establishes that root-canal filling materials should have a radiopacity of at least 3 mm aluminum. According to the ANSI/ADA (9), endodontic filling materials should present a difference in radiopacity equivalent to at least 2 mm aluminum in comparison with bone or dentine. Aluminum was chosen as a reference, because its radiopacity was reported to be similar to dentin (10,11). According to the standardized protocol, a D-speed occlusal film should be irradiated with an aluminum stepwedge at 65±5 kVp at a target distance of 30 cm, the radiographic image must be obtained by the chemical processing of radiographic film, and the radiopacity must be evaluated by an optical densitometer. In current studies, this method was modified either by digitizing the chemically processed conventional radiographic films (12) or by using a direct digital technique eliminating the need for an optical densitometer (13-16).

Mineral trioxide aggregate (MTA) is indicated for a series of endodontic applications: Perforation sealing, pulp capping, apexification, obturation, and retro-filling (14). MTA Fillapex, a relatively new MTA-based root-canal filling material, has a similar composition to MTA except from the addition of natural resin and nanoparticulate silica. In order to use MTA Fillapex as a new option for root-canal filling material, its physical properties including radiopacity must be confirmed in agreement with the characteristics cited by Grossman (17) for the ideal sealer. To our knowledge, the radiopacity of MTA Fillapex has been investigated only by Meirelles Vidotto et al. (18). The aim of this study was to evaluate the radiopacity of MTA Fillapex and to compare it with four currently used root-canal filling materials using digital radiography.

MATERIALS AND METHODS

Radiopacity of MTA Fillapex, Adseal, AH Plus, Endomethasone and gutta-percha cones were evaluated in this study. The compositions and the manufacturers of the materials are listed in Table 1.

Table 1: The composition and the manufacturers of the root-canal filling materials used in the present study.

MATERIAL	COMPOSITION	MANUFACTURER
MTA FILLAPEX	Salicylate resin, diluting resin, natural resin, bismuth trioxide, nanoparticulated silica, MTA, pigments	Angelus Dental Industry Products, Brazil
ADSEAL	Epoxy oligomer resin, ethylene glycol salicylate, calcium phosphate, bismuth subcarbonate, zirconium oxide, polyaminobenzoate, triethanolamine, calcium oxide	Meta Biomed, Korea
AH PLUS	Epoxy resin, zirconium oxide, calcium tungstate, silicone oil, iron oxide	Dentsply DeTrey GmbH, Konstanz, Germany
ENDOMETHASONE	Hydrocortisone acetate, thymol iodide, barium sulphate, zinc oxide, magnesium stearate	Septodont, France
GUTTA-PERCHA	Gutta-percha, zinc oxide filler, heavy metal radiopacifier, plasticizer	Diadent, Korea

Sample Preparation

Ten plexiglass plates containing five wells measuring 1 mm in depth and 5 mm in internal diameter were fabricated. Root-canal filling materials were manipulated according to the manufacturers' instructions. Ten standard samples were prepared from each material by pouring the manipulated materials into the wells and covering with glass plates on each side to allow for the removal of excessive material. Gutta-percha cones were warmed and fitted into the remaining well. The filled plexiglass plates were kept in a moist chamber at 37ºC until materials were completely set. The root-canal filling materials were placed on the plexiglass plates in the same order to easily locate the materials during the radiopacity analysis.

Digital radiographs

Each one of the plexiglass plates containing the root-canal filling materials were placed on storage phosphor plate (Vistascan PSP, Dürr Dental, Bietigheim-Bissingen, Germany; size 4; 5.7x7.6 cm) along with the aluminum stepwedge that was used as a standard for the comparison of radiopacity of the test materials (Figure 1). The stepwedge was made of 99% pure aluminum and increased in thickness by 1 mm each step, with a thickness range of 1 to 15 mm.

Figure 1: Storage phosphor plate with root-canal filling material samples and aluminum stepwedge in place for radiographic exposure.

Radiographic images were obtained using a dental x-ray unit (Evostyle NG, New Life Radiology, Torino, Italy) operating at 70 kVp, 8 mA, with exposure set at 0.2 sec (as instructed for phosphor plates), and an object-to-focus distance of 30 cm. For the positioning of the phosphor plate and for assuring that the object-to-focus distance was standardized, an acrylic device with metallic holders was prepared, following a model used in previous studies (13,14). This device maintained the head of the x-ray machine in the same position with the central beam directed at a 90º angle to the surface of the plexiglass plate/ phosphor plate set-up. Exposed plates were scanned immediately after exposure using image plate scanner (Vistascan Mini, Dürr Dental, Bietigheim-Bissingen, Germany) following the manufacturer's standard instructions to obtain the gold standard images. The same phosphor plate was used for all exposures to avoid any possible difference between the plates. The images were viewed using the system's own software (DBSWIN 5.2.0, Dürr Dental, Bietigheim-Bissingen, Germany) (Figure 2).

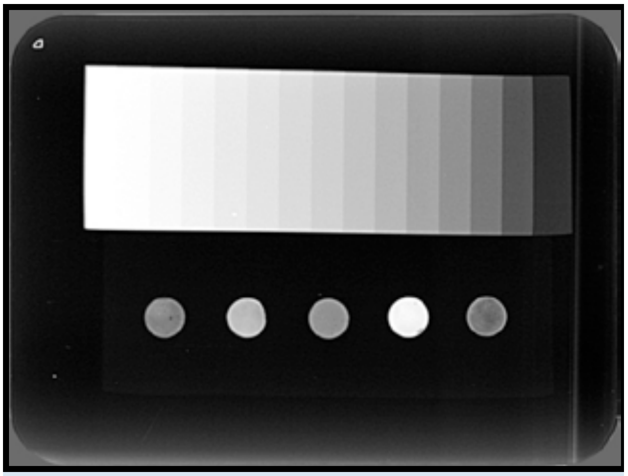

Figure 2: Digital radiographic image of root-canal filling material samples and aluminum stepwedge.

Measurement of mean grey values

The number of grey shades in the digital image is given by the number of binary digits (bits) used to define a pixel. Depending on the system, the grey values may be from 8- to 16-bit. In the 16-bit system used, the darkest grey shade (black) is usually defined by the value zero while the lightest (white) had a value of 65536.

Mean grey values of the materials and each step of the stepwedge were measured using the histogram analysis function of the software. Three measurements were obtained for each sample and for each step of the aluminum stepwedge, and the mean values of these readings were calculated. The measurements were performed by one evaluator who was blinded to the identity of the materials. Each mean grey value was then converted to its aluminum equivalent using the stepwedge values in Curve Expert 1.4 program (www.curveexpert.net).

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) for Windows 15.0 software (SPSS Inc., Chicago, IL, USA) using descriptive statistics (mean, standard deviation), Kolmogorov-Smirnov test, Kruskal Wallis test, and Bonferroni adjusted Mann-Whitney U test, at the 5% significance level.

RESULTS

Table 2 shows the mean values and the standard deviations of the radiographic density values of the steps of the aluminum stepwedge. The means and standard deviations of the radiographic density values and millimeter equivalents of aluminum for each of the materials investigated are shown in Table 3. All materials were found

Table 2: Radiographic densities of steps of aluminum stepwedge.

Steps of aluminum stepwedge (mm)	Radiographic density Mean ± SD	Median
0	49857,40 ± 354,20	49576
1	52124,20 ± 209,09	52073
2	54601,80 ± 45,77	54585
3	56348,00 ± 242,50	56357
4	57783,40 ± 177,65	57727
5	58853,00 ± 237,72	58884
6	59778,00 ± 134,46	59782
7	60506,80 ± 158,12	60481
8	61021,80 ± 181,65	60980
9	61570,00 ± 192,04	61494
10	62072,80 ± 171,82	62035
11	62474,80 ± 99,52	62429
12	62823,20 ± 160,29	62763
13	63035,60 ± 102,51	63024
14	63365,00 ± 69,89	63354
15	63687,00 ± 93,98	63650

Table 3: Radiographic densities and radiopacity values of root-canal filling materials, expressed in millimeters of aluminum equivalent.

Filling materials	Radiographic density Mean ± SD	Radiopacity (mm Al) Mean	*p*
MTA Fillapex	59143,40 ± 942,03	5,30	0,001**
Adseal	57360,40 ± 496,32	3,71	
AH Plus	61955,40 ± 224,71	9,70	
Gutta-percha	60374,80 ± 442,25	6,82	
Endomethasone	57306,00 ± 643,36	3,67	

Kruskal Wallis Test, ** p<0.01

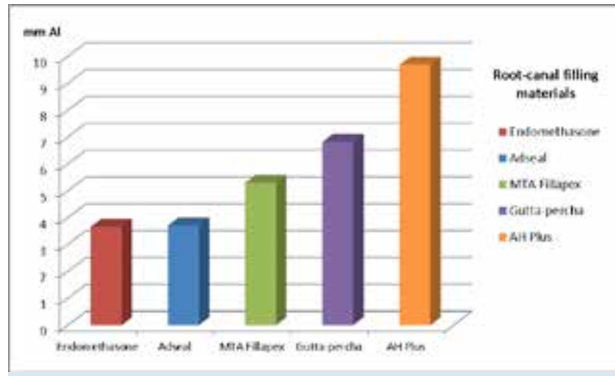

Figure 3: Comparative radiopacity of root-canal filling materials expressed in mean equivalent aluminum thickness.

Table 4: Comparison of mean radiographic density values of the root-canal filling materials tested.

	Radiographic density *p*
MTA Fillapex / Adseal	0,003*
MTA Fillapex / AH Plus	0,003*
MTA Fillapex / Gutta-percha	0,047
MTA Fillapex / Endomethasone	0,003*
Adseal / AH Plus	0,003*
Adseal / Gutta-percha	0,003*
Adseal / Endomethasone	0,917
AH Plus / Gutta-percha	0,003*
AH Plus / Endomethasone	0,003*
Gutta-percha / Endomethasone	0,003*

Bonferroni-adjusted Mann-Whitney U test, * p<0.005

to present radiopacity values above ISO and ANSI/ADA specifications (8,9). In decreasing order of radiopacity, AH Plus (9.70 mm Al) was the most radiopaque material, followed by gutta-percha (6.82 mm Al), MTA Fillapex (5.30 mm Al), Adseal (3.71 mm Al), and Endomethasone (3.67 mm Al) (Table 3 and Figure 3).

AH Plus presented a mean radiographic density value significantly higher than all other endodontic filling materials ($p<0.005$). Gutta-percha and MTA Fillapex exhibited mean radiographic density values significantly higher than those of Adseal and Endomethasone ($p<0.005$). No statistically significant differences were observed between the remaining materials ($p>0.05$) (Table 4).

DISCUSSION

Radiopacity of an endodontic material provides a contrast between adjacent anatomical structures and filling material; and it improves the radiographic diagnosis of voids and improper contours (14,19).

The molecular structure and the thickness of a material have a major effect on the radiopacity. Therefore, the international standards for the radiopacity of root-canal filling materials have suggested the use of test material samples prepared in molds in order to obtain standard discs (8). In this study, plexiglass, transparent and low-cost plates were used in the preparation of the test samples. To reduce the volume of material used for the preparation of the sample, and to allow for more samples to be placed in the central part of the digital receptor (13), the diameters of the wells made in the plexiglass plates were decreased from the ANSI/ADA specification of 10 mm (9) to 5 mm. According to Tagger and Katz (12), the main advantage of the method used is that the image can be meticulously examined and directly measured on the computer screen under high magnification, compensating for this smaller-diameter and, consequently, smaller surface available for evaluation.

The technique used to evaluate the radiopacity of dental materials compared specific thickness of materials to aluminum stepwedges under controlled radiographic conditions. In this experimental study, the object-to-focus distance of 30 cm is maintained with the same exposure parameters (70 kVp, 8 mA, with exposure set at 0.2 sec).

The radiopacity of a dental material specimen is usually expressed in terms of equivalent aluminum thickness (in millimeters) using a reference calibration curve. The aluminum stepwedge was chosen as the standard for measuring radiopacity, because it allows the comparison of specific sample thicknesses with aluminum stepwedge under typical radiographic conditions (20,21). All endodontic filling materials evaluated in this study had a greater radiopacity than the minimum recommended by the ISO (8) and ANSI/ADA (9) specified limit.

Dentin specimens (1 mm in thickness) prepared from freshly extracted teeth have been used as control group in addition to test specimens in some of the previous studies (22-24). ISO and ANSI/ADA standards stipulate the minimum radiopacity be equal to or greater than that of an equivalent thickness of aluminum. Although the radiopacity of dentin specimens may vary among individuals, pure aluminum provides a constant value. Therefore, inclusion of a dentin specimen as control was not preferred in this study.

A number of studies have investigated the radiopacity of different endodontic filling materials, and the results were expressed as millimeters of aluminum equivalent. The methodology used in these studies was mostly based on the measurement of radiopacity on occlusal films through an optical densitometer (4,22,23) or measurement of the pixel grey value using a specific software after digitization of conventional films (12). Digital radiographic systems were used in recent studies (13-16) for radiopacity measurements of endodontic filling materials. In the present experimental model, digital images of root-canal filling materials and steps of an aluminum stepwedge acquired using a digital phosphor plate, and a digital system for scanning, capturing and reading were used. This system does not need conventional radiographic film or its chemical processing, thus saves time and decreases stages that could interfere with the final radiographic quality (25).

It has been demonstrated in numerous studies that several factors may affect the radiopacity of root-canal filling materials. In addition to the composition of the material and the type/percentage of the radiopacifier, the most significant factors contributing to radiographic density were material thickness, exposure settings (exposure time, kVp, mAs, object-to-focus distance), film speed, angulation of the x-ray beam, type of imaging technique, developing process, and the method used for the measurement of density (26,27). In addition to aforementioned factors, differences in the aluminum alloy of the stepwedge and different material manufacturers are also important considerations.

Because of the differences in the methodology used to determine the radiopacity values, it is difficult to compare the present results with the previous studies. As digital radiography systems use different methods of measuring x-ray radiation, the radiopacity recorded on conventional or digitized films may not be similar to the radiopacity recorded on a digital sensor (24).

AH Plus, a two component paste root-canal filling material, based on polymerization reaction of epoxy resin-amines, contains zirconium oxide which contributes to its having a greater radiopacity in relation to the other materials tested (28). In this study, the radiopacity of AH Plus was found to have the highest value as 9.70 mm of aluminum; it was reported to be 11.2 (13), 10.41 (16), 9.8 (29), 9.4 (18) and 9.0 (12) mm of aluminum in previous studies. Adseal was found to have the second lowest radiopacity value (3.71 mm of aluminum) among the root-canal filling materials tested in this study. In a study with similar methodology by Taşdemir et al. (16), the radiopacity of Adseal was reported to be 3.09 mm of aluminum. Gutta-percha cones contain radiopacifier agents like barium sulphate and zinc oxide. Previous studies indicated that all gutta-percha cone brands exceeded the minimal radiopacity requirement (30). In our study, radiopacity of gutta-percha was determined as 6.82 mm aluminum. MTA-based root-canal filling material MTA Fillapex exhibited a satisfactory radiopacity value (5.30 mm aluminum), however, lower than that found by Meirelles Vidotto et al. (6.5 mm aluminum) (18). But it is almost the same as stated by the material manufacturer to be 77% greater than 3 mm of the aluminum stepwedge (5.31 mm aluminum). It may be concluded that the present results concerning the opacity values of five different root-canal filling materials are in accordance with the previous reports.

CONCLUSION

Based on the methodology employed and results obtained, all of the root-canal filling materials studied met the minimum radiopacity standard recommended by the ISO and ANSI/ADA. MTA Fillapex, which is a new canal sealer, was the third most radiopaque material among all materials tested in this study and proved to be suitable for endodontic usage in terms of radiographic assessment.

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