Radiopacity Evaluation of Calcium Aluminate Cement Containing Different Radiopacifying Agents

Fabiano Gamero Aguilar, DDS, MSc, * *Lucas da Fonseca Roberti Garcia, DDS, MSc, PhD,* * *Hebert Luis Rossetto, B Eng, MSc, PhD,* † *Luiz Carlos Pardini, DDS, MSc, PhD,* ‡ *and Fernanda de Carvalho Panzeri Pires-de-Souza, DDS, MSc, PhD* *

Abstract

Introduction: The aim of this study was to evaluate the radiopacity of calcium aluminate cement (EndoBinder) with 3 different radiopacifiers (bismuth oxide, zinc oxide, or zirconium oxide) in comparison with gray mineral trioxide aggregate (GMTA), white MTA, and dental structures (enamel and dentin). **Methods:** Eighteen test specimens of each cement with thicknesses of 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 mm (n = 3) were made by using a stainless steel matrix and were adapted to a standardizing device (8 × 7 cm) with a graduated aluminum stepwedge varying from 2.0–16.0 mm in thickness. To compare the radiopacity of the cements with that of dental structures, slices of first molars with a thickness increasing from 0.5–3.0 mm were obtained and placed on the standardizing device. One occlusal radiograph for each tested cement was taken, with exposure time of 0.1 seconds and focus-film distance of 20 cm. Films were processed in an automatic device, and the mean radiopacity values were obtained by using a photodensitometer. **Results:** Mean values showed that the thicker the specimen was, the greater was its radiopacity. Only EndoBinder + bismuth oxide (EBBO) and GMTA demonstrated radiopacity values greater than 3.0 mm of the aluminum scale for all thicknesses. When zinc oxide was used as radiopacifier agent, EndoBinder only reached the desired radiopacity with a thickness of 2.0 mm, and with zirconium oxide it was 2.5 mm. **Conclusions:** Bismuth oxide was the most efficient radiopacifier for EndoBinder, providing adequate radiopacity in all studied thicknesses, as recommended by ISO 6876, being similar to GMTA. *(J Endod 2011;37:67–71)*

Key Words

Calcium aluminate cement, mineral trioxide aggregate, optical density, radiopacity

Endodontic therapy has reached high success rates thanks to the development of techniques and materials that allow a large portion of clinical cases to be resolved, including apexification, pulpotomy, paraendodontic surgeries, and repair of root resorptions and perforations, which require a specific cement sealant (1).

An ideal filling material must be atoxic, noncarcinogenic, nongenotoxic, biocompatible with adjacent tissues, insoluble in oral fluids, dimensionally stable, and radiopaque (2, 3). Because there is no ideal restorative material used in endodontics, mineral trioxide aggregate (MTA), which was originally developed as a cement for retrograde filling (4), has been used for pulp capping (5), pulpotomy (6), apexogenesis and to repair root perforations (7), treatment of traumatized teeth with incomplete apexification (8), root resorptions (9), as an intracoronal barrier before dental bleaching and apical plug (10), as well as filling material (11). It was made commercially available in 2 forms, gray and white, differing only as regards the reduction in ferrous oxide concentration in white MTA (WMTA) (12).

Nevertheless, some of the negative points of MTA must be pointed out, such as the long setting time, which makes it difficult to insert in deep areas of the root canal (13). It is difficult to manipulate, which leads to the formation of porosities after spatulation and makes it highly unstable (14). It has low resistance to compression (11), low flow capacity (15), high cost (16), high rate of dental structure staining (9, 17), high solubility in a humid environment (18, 19), as well as presence and release of arsenic (20, 21). Effects such as these justify the development of new biocompatible materials with adequate mechanical properties (19).

A new calcium aluminate–based endodontic cement (Patent Number PI0704502-6, 2007) called EndoBinder (Binderware, São Carlos, SP, Brazil) has been developed, with the intention of preserving the properties and clinical applications of MTA without its negative characteristics. It is a material composed of (% by weight): Al_2O_3 (≥68.5), CaO (≤31.0), SiO_2 (0.3–0.8), MgO (0.4–0.5), and Fe_2O_3 (<0.3), which, according to Pandolfelli et al (22) and Jacobovitz et al (23), presents suitable biological and antimicrobiological properties. The cement is produced by the process of calcining Al_2O_3 and $CaCO_3$ at temperatures between 1315°C and 1425°C, the most feasible method for the production of materials with a more uniform composition. The calcium aluminate formed is cooled and then triturated until an adequate particle size is obtained. In a general approach, the formation of EndoBinder can be described by the following chemical reaction: $CaCO_3 + Al_2O_3 = Ca(AlO_2)_2 + CO_2$.

Radiopacity is an important physical property for endodontic materials. In accordance with the ISO 6876 standard (24), endodontic cements must have a radiopacity

From the *Department of Dental Materials and Prosthodontics, Ribeirão Preto School of Dentistry, University of São Paulo, Ribeirão Preto, SP, Brazil; †Binderware Biomaterials Ltda, São Carlos, SP, Brazil; and ‡Department of Morphology, Stomatology and Physiology, Ribeirão Preto School of Dentistry, University of São Paulo, Ribeirão Preto, SP, Brazil.

Address requests for reprints to Profa. Dra. Fernanda de Carvalho Panzeri Pires-de-Souza, Faculdade de Odontologia de Ribeirão Preto, USP, Departamento de Materiais Dentários e Prótese, Avenida do Café, s/n, Bairro Monte Alegre, CEP 14040-904, Ribeirão Preto, São Paulo, Brasil. E-mail address: ferpanzeri@forp.usp.br.
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greater than 3.0 mm in relation to the aluminum scale (Al). In accordance with ANSI/ADA specification no. 57 (25), all endodontic cements must be 2.0 mm of Al more radiopaque than dentin or bone. Thus, a radiopacifying agent must be added to EndoBinder to allow the cement and the quality of the root canal filling to be radiographically visualized and for the cement to be distinguished from the adjacent anatomic structures (16).

The ideal radiopacifying agent should be inert, contaminant-free, and atoxic, and the minimum possible quantity of it should be added (16), without ignoring that this minimum quantity must be of a material that is composed of elements with high atomic numbers. The bismuth oxide used in the composition of MTA increases the radiopacity of endodontic cements, with values higher than those equivalent to the Al scale (26), but it is not inert and interferes in the mechanism of hydration of the material (27), diminishing the release of calcium ions by the cement (28), altering its reparative capacity (29) and its physicochemical properties (30). Therefore, alternative radiopacifiers have been proposed (3, 31). Zinc and zirconium oxides are radiopacifying agents used in dental materials for prosthetic and implant purposes and do not present toxicity (32). Thus, the aim of this study was to evaluate the radiopacity of the calcium aluminate cement (EndoBinder), by using 3 different radiopacifying agents (bismuth oxide, zinc oxide, or zirconium oxide), in comparison with gray MTA (GMTA), WMTA, and dental structures (enamel and dentin). The null hypotheses tested were that there would be no difference in the level of radiopacity of the tested cements, irrespective of the radiopacifying agent used, among them and in comparison with GMTA and WMTA, and that all would present the recommended levels of radiopacity in relation to the aluminum scale and greater than that of enamel and dentin.

Materials and Methods

Standardization of the Radiographic Procedure

All the geometrical factors that might interfere in the formation of the radiographic image were standardized by creating a transparent acrylic matrix called the standardizing device, measuring 8 × 7 cm. These measurements corresponded to the width and length of an occlusal radiographic film, which was adapted to the bottom part of the device, fixed on lateral channels (Fig. 1*A*). The upper part of the device was composed of steps that gradually increased in thickness every 0.5 mm up to the thickness of 3.0 mm. Therefore, the first step was 0.5-mm thick, the second 1.0-mm, and so on, up to the last step of 3.0-mm thickness, which was a total of 6 steps. On each step, 3 circular orifices measuring 5 mm in diameter were opened in which to place the material to be radiographed, totaling 18 orifices.

An opening was made in the center of the thickness standardizing device, suitable for adapting the aluminum scale (stepwedge), measuring 10 × 32 mm, and scaled in 8 steps, with incremental thicknesses of 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, and 16.0 mm, according to the recommendations of Manson-Hing and Bloxom (33). The purpose of this stepwedge was to simulate, by means of shade nuances produced after exposure and processing of the radiographs, the densities of the structures of the oral cavity in comparison with the hard and soft tissues for laboratory analyses of the quality of the radiographic images to show the homogeneity of the procedures and to detect possible variations during the procedures of the radiographic techniques and processing.

To certify that the acrylic material of the thickness standardizing device would not interfere with the radiographic image of the materials, an initial radiographic image was taken with an occlusal film (Insight; Kodak, New York, NY) and the stepwedge only.

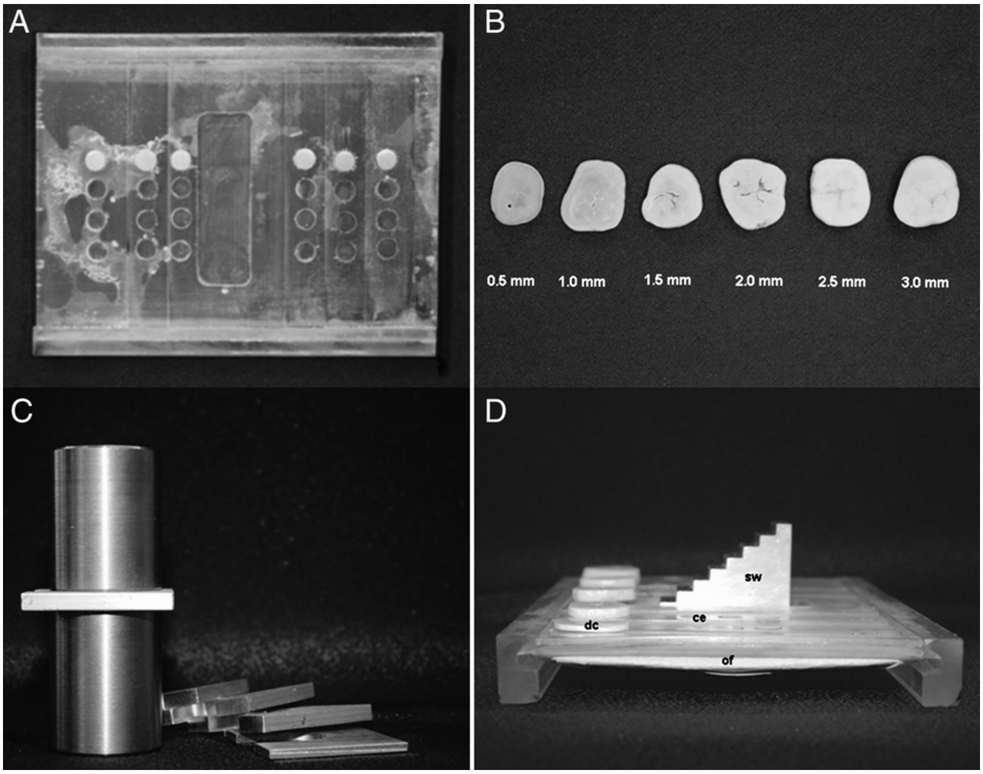

Figure 1. Standardizing device used to determine OD of the tested cements (*A*), dental cuts (cervical region, mesiodistal direction) (*B*), stainless steel matrix used to make the test specimens (*C*), and standardizing device assembled with cements (ce), dental cuts (dc), occlusal film (of), and stepwedge (sw) (*D*).