Differences in Aluminum Equivalent Values of Endodontic Sealers: Conventional Versus Digital Radiography

B. Guniz Baksi, DDS, PhD, B. Hakan Sen, DDS, PhD,† and Tan Firat Eyuboglu, DDS†*

Abstract

The aims of this study were to compare film and digital radiography in assessing the radiopacities of root canal sealers and to establish the relation in aluminum equivalent values of different methods. Standard disks of 5 different sealers were exposed together with an aluminum step wedge by using occlusal films and storage phosphor plates. Optical density of the sealers was evaluated by transmission densitometry, and mean gray values were determined by digital analysis. The data were analyzed by using two-way analysis of variance ($P = .05$). Pairwise comparisons were made by using Tukey post hoc and paired t tests ($P = .05$). The order from the most radiopaque to the most radiolucent sealer was the same for both methods; however, aluminum equivalent values determined by transmission densitometry were significantly higher ($P < .01$). Aluminum equivalent values of the 2 radiographic methods were 7%–20% different. The International Standards Organization standard for the radiopacity of dental root canal sealing materials needs modifications for digital systems. *(J Endod 2008;34:1101–1104)*

Key Words

Digital, radiography, radiopacity, root canal sealer, storage phosphor plate

From the *Department of Oral Diagnosis and Radiology and †Department of Restorative Dentistry and Endodontology, School of Dentistry, Ege University, Bornova, Izmir, Turkey.

Address requests for reprints to Prof Dr B. Guniz Baksi, Ege Universitesi, Dishekimligi Fakultesi, Oral Diagnoz ve Radyoloji Anabilim Dali, Bornova 35100, Izmir, Turkey. E-mail address: guniz.baksi@ege.edu.tr.

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Radiopacity is a recognized scientific property of many dental materials. It is convenient that this characteristic should be reduced to and expressed by a simple numeric measure. One of the most recommended methods to measure the radiopacity is the use of an aluminum step wedge as a reference standard. Both International Standards Organization (ISO) and American National Standards Institute/American Dental Association (ANSI/ADA) have published standardized procedures for quantifying the radiopacity of several types of dental materials, referring at least 98% pure aluminum wedge as a reference (ISO 6876/2001) (1, 2). In most of the published studies, aluminum step wedge with an occlusal film has been used for the determination of optical density values of various dental materials such as glass ionomer cements, resin composites, and root canal sealers.

Recently, digital analysis method has been proposed for the determination of gray pixel values. Few studies adopting this method have used the direct digital technique (3, 4), whereas some others have preferred the indirect method and therefore scanned the occlusal films for image acquisition (5). In either case, it is surprising to note that the comparison of digital and film images with regard to the radiodensity of dental materials has been rarely investigated (3, 6–8). Although 2 radiographic methods yielded varying results in some of the above mentioned studies, the results that were interpreted only with regard to the order of radiopacities of the materials were still found to be interesting. Consequences for inconsistent findings and/or reasons other than physical characteristics of materials were rarely discussed.

Digital imaging technique is an emerging area of radiology that offers many potential benefits to endodontic practice and follow-up (9, 10). Other than very well-known advantages of the digital systems, the main advantage they offer is computer-based image processing and analysis. Eight studies to date have investigated the radiodensity of root canal sealers by using either direct or indirect digital radiographic methods (4–6, 11–15). In one of the recent studies evaluating the effect of sealer opacity on the overall radiodensity of root fillings, it was clearly demonstrated that the current ISO standard for determination of the radiopacity of dental root canal sealing materials needs additions or modifications for electronic imaging (16).

The aims of this study were therefore (1) to compare conventional film and digital radiography in assessing the radiopacities of various root canal sealers and (2) to establish any possible relation in aluminum equivalent values obtained by different radiographic methods.

Materials and Methods

Preparation of the Samples

Five endodontic sealers evaluated in this study were as follows: Acroseal, Specialités-Septodont, Saint Maur-des-Fossés, France; Diaket, 3M Espe, Seefeld, Germany; Guttaflow, Colténe/Whaledent, Langenau, Germany; Pulp Canal Sealer, Kerr Manufacturing Co, Romulus, MI; and RoekoSeal, Colténe/Whaledent. All procedures were accomplished according to the ISO standard for dental root canal sealing materials (6876/2001).

All sealers were mixed according to the manufacturers' instructions. A Teflon ring mold with an internal diameter of 10 mm and a depth of 1 mm was placed on a glass slab. Each material was packed into the mold until it was slightly overfilled and then covered with another glass slab until it was set. Three samples were made of each material. Specimen porosity content was checked on radiographic films (Ektaspeed-Plus; Eastman Kodak, Rochester, NY) by using a 10× magnifying scale loupe (Peak,

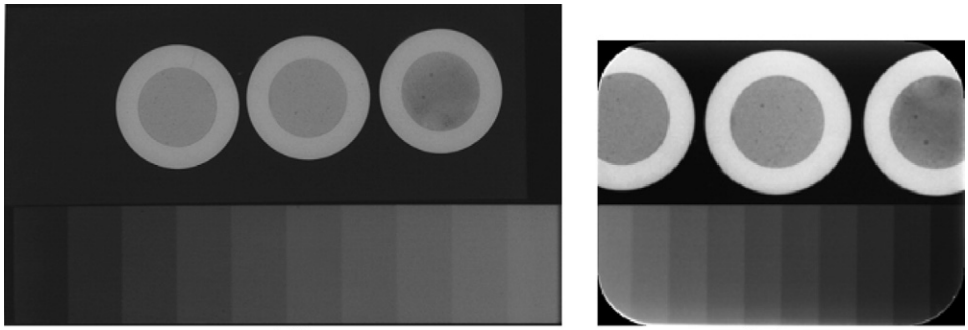

Figure 1. Occlusal film (*A*) and storage phosphor plate (*B*) images showing the aluminum step wedge with 3 samples of 1 of the root canal sealers used in the study.

Tokyo, Japan). Specimens with porosities were excluded from the study and replaced to provide 3 homogeneous specimens of each material.

An aluminum step wedge, made of 99.5% pure aluminum and with ten 0.5-mm-thick incremental steps, was used as a standard for comparison of radiodensity of the test materials and to control any variation in exposure and processing.

Irradiation and Processing of the Radiographs

Each sample of the sealers and an aluminum step wedge were placed directly in the center of an Ektaspeed occlusal film (Eastman Kodak Co) (Fig. 1*A*). The film was faced on a 2-mm-thick lead sheet to avoid back-scattered radiation. Radiographs were obtained with a dental x-ray unit (Anthos, Imola, Italy) with 2.5 mm aluminum equivalent total filtration, at 65 kVp, 10 mA, 0.30 seconds by using a standardized focus-to-film distance of 30 cm. One unexposed occlusal film from the same batch was processed in an identical manner to obtain base plus fog density.

The films were processed at once in an automatic processor (Dürr XR 24, Beitigheim, Germany) at 28°C for 4.3 minutes with fresh solutions (Hacettepe, Ankara, Turkey) mixed according to the manufacturer's instructions.

Digital Radiographs

Digora storage phosphor plates (Soredex Corporation, Helsinki, Finland) were exposed by using the same x-ray machine and same exposure parameters. An optical bench was used to standardize geometric projection. Exposed plates were scanned immediately after exposure by using Digora fmx scanner (Fig. 1*B*). The resulting images were transferred as 8-bit TIFF files to a personal computer, where they were analyzed with a software program (Image Tool 3.0 SDK; University of Texas Health Sciences Center, San Antonio, TX) developed particularly for dental image analysis.

Densitometric Evaluation of the Radiographs

Radiographic densities of the samples, each step of the step wedge, and the unexposed film were measured with a digital transmission densitometer (Macbeth TD 932, Newburgh, NY) with an 0.1-mm aperture. Three readings were made for each film; the mean was calculated and corrected for base plus fog to give the radiographic density expressed as optical density units (ODU).

Storage phosphor plate images were displayed on a 17-inch SVGA color monitor (Lite-on, Guangdong, China; 1024 × 768 pixels). The histogram analysis function of a software program (Image Tool 3.0 SDK; University of Texas Health Sciences Center) developed particularly for dental image analysis was used for the densitometric evaluation of the digitized images. First, the area of interest with a size of approximately 0.86 cm^2 was selected on each step of aluminum step wedge, and its mean gray value (MGV) was calculated. The same procedure was repeated for each of the test materials. Three determinations of radiodensity were made, and the mean values and standard deviations were calculated. The results were expressed as MGV of each material.

Each ODU and MGV was then converted to its aluminum equivalent by using the step-wedge values in Curve Expert 1.3 program (http://curveexpert.webhop.biz/).

The data were first analysed with two-factor analysis of variance (ANOVA). The type of the sealers and the densitometric methods were the factors. Then, Tukey post hoc test and paired t test were used to make pairwise comparisons. Level of significance was set at $P < .05$.

Results

Aluminum equivalent values calculated by using ODU of film radiographs and mean pixel values of digital images are shown in Table 1. Two-factor ANOVA revealed that there were differences among both the sealers ($P < .001$) and 2 densitometric methods ($P < .001$).

Radiographic Film Measurements

The most radiopaque material among the test objects was Guttaflow, with an aluminum equivalent value of 6.13 mm. The order from the most radiopaque to the most radiolucent was as follows: Guttaflow, PCS, Roekoseal, Diaket, Acroseal.

Pairwise comparisons revealed significant differences between all sealers ($P < .05$), except between Diaket and Acroseal ($P > .05$).

TABLE 1. Mean ± Standard Deviation of Aluminum Equivalent Values of Different Sealers Obtained by Using Optical Density (ODU) and Pixel İntensity (MGV) Measurements

	Acroseal	Diaket	Guttaflow	PCS	Roeko
ODU	2.04 ± 0.24	2.19 ± 0.10	6.13 ± 0.21	4.66 ± 0.79	3.17 ± 0.22
MGV	1.90 ± 0.15	2.00 ± 0.07	5.84 ± 0.53	3.77 ± 0.67	2.83 ± 0.17

MGV, mean gray value; ODU, optical density units.