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# A standard for radiopacity of root-end (retrograde) filling materials is urgently needed

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## Abstract

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**Aim** To assess the radiopacity of materials used, or recommended for use, as apical root-end (retrograde) fillings.

**Methodology** The radiopacity of 14 materials falling into the category of root-end filling materials was measured in equivalent millimetres of aluminium (mm Al) using a new computerized method. These included temporary or intermediate sealing materials; composite, compomer and GIC filling materials; EBA-derived cements; amalgam, etc. Gutta-percha cone material was added as a control. Samples of 1 mm thickness were radiographed on periapical film alongside an

aluminium step wedge calibrated in millimetres, and the opacity of the materials, in greyscale or pseudo-colour, was compared with the equivalent step.

**Results** The radiopacity ranged from 1.75 mm Al to >10 mm Al. The lower range appears insufficient for routine clinical detection when it is compared with the minimal requirement for intracanal fillings.

**Conclusions** Because of the proliferation of root-end filling materials with a broad range of radiopacity, an international standard stipulating the required minimal radiopacity, as well as other properties, is needed urgently. It should be based on *in vitro* results and on large-scale clinical radiographic surveys.

**Keywords:** apicoectomy, computerized, radiopacity, retrograde-filling, standard.

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## Introduction

Apical resection or apicoectomy followed by root-end (retrograde) filling is a common treatment modality for failed root fillings (Allen *et al.* 1989). Recently, the predominance of silver amalgam as a root-end filling material has been challenged. Long-term retrospective follow-up surveys (Frank *et al.* 1992) revealed that cases considered radiographically successful initially started to show signs of breakdown 10 years or more after the treatment and the success rate dropped to 57.7% ( $n = 104$ ). These and other similar findings were interpreted as evidence of poor biocompatibility, lack of long-term stability, inadequate adaptation to the cavity

walls and late leakage of the amalgam. This coincided with the peak of the public awareness of toxicity because of mercury in dental fillings and resulted in re-evaluation of all aspects of the use of amalgam in dental practice (Corbin & Kohn 1994).

The quest for a substitute to amalgam has induced clinicians to attempt to use a great variety of materials. Torabinejad & Pitt Ford (1996) published an extensive critical review of materials that had been cited in the literature until 1995. One of the disadvantages noted in some of the materials was lack of sufficient radiopacity. This point has been discussed by Shah *et al.* (1996) and by Laghios *et al.* (2000), but they assumed that there is a standard for radiopacity of root-end (retrograde) filling materials. In fact, the old American National Standards Institute/American Dental Association (1983) is somewhat ambiguous. The text states that it covers 'materials intended for obturating the root canal space', but it does not mention specifically root-end (retrograde) fillings and the question can be raised: is a root-end cavity

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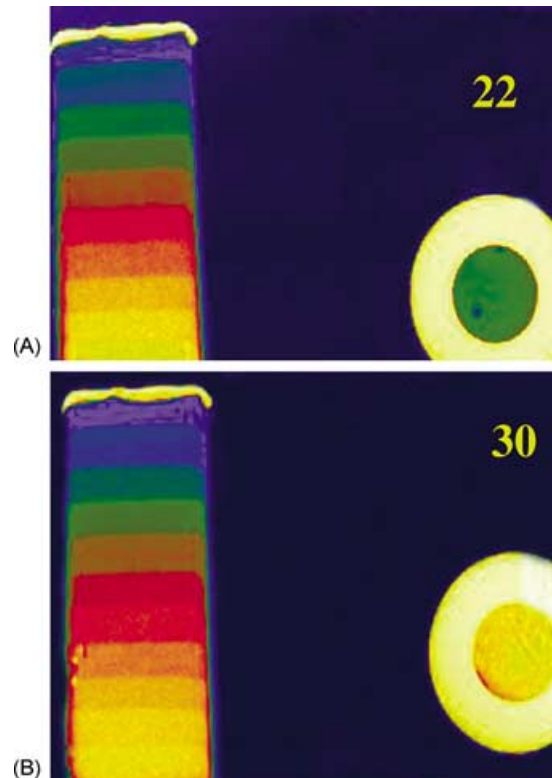
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preparation part of the root canal space? The revised edition of the standard in 1993 is still vaguely restrictive, stating that it is intended 'for materials used in endodontics within the tooth to seal the root canal space'. The new ADA-Standards Committee on Dental Products (SCPD) specification that should replace it in 2003–2004 will probably clearly state the categorical limitation stipulated by ISO Standard no. 6876 (1988). This standard's scope is: 'materials for use in the obturation of the root canal in the orthograde fashion only'. This definition, dating from the initial ISO Standard no. 6876 published in 1986 (ISO 1986) has remained unchanged in its revision of 1991 and 1999 draft and it indisputably leaves out root-end filling materials. In fact, they are excluded from any presently available standard covering the physical properties of dental materials (F. Lentine, personal communication).

The purpose of this paper is to assess the radiopacity of a variety of materials that are being used or suggested for use as root-end filling materials, and to attempt to reach a preliminary conclusion about their suitability from the point of view of radiopacity, at least according to the specification concerning root canal obliteration materials. The exact degree of minimal radiopacity is still to be established, but it will certainly be higher. The method and the findings may be useful to the appropriate certifying bodies and stimulate them to set up a new specification: 'Properties of the root-end (retrograde) filling materials – physical properties'.

## Materials and methods

A recently published method for direct measurement of the radiopacity of root canal filling materials has been selected for this study (Tagger & Katz 2003). Based on modern computational techniques, it makes it possible to carry out an effective survey of numerous samples. Steel washers each of 1 mm thickness and with a central bore of 6 mm diameter serve as sample carrier. As the washers are disposable, they are placed individually on 1 in. × 3 in. histological glass section carriers, and then filled with the test substance and left undisturbed until testing (if necessary in a cabinet with controlled humidity and temperature). The glass carrier with the washer is positioned on a periapical X-ray film and radiographed with an aluminium step wedge and a code number placed alongside the specimen. The resultant radiograph is digitized for analysis with either a custom-made program or with advanced image treatment software, e.g. ADOBE PHOTOSHOP™ (Adobe Systems, USA). The opacity of the specimen is compared with that of one of the steps



**Figure 1** Partial view of periapical film illustrating positioning of the washer-sample carrier with the aluminium step wedge. Radiograph slightly retouched and rendered in pseudo-colour. The first step is lined with lead (yellow). The steps can be distinguished clearly; note the lack of homogeneity of the sample enhanced by the hue. (A) Sample 22 – composite Z 100, opacity 3–4 mm Al. Note darker entrapped air bubble (at 7 o'clock of specimen) and apparent lack of wetting of walls by material. (B) Sample 30 – Diaket, opacity 11 mm Al. Hue indicates flaw in filling of sample well (lower left quadrant). It was probably caused by inserting the material while it was already setting.

of the step wedge and read in equivalent millimetres of aluminium (mm Al). Use of pseudo-colour (Fig. 1) easily permits direct comparison of the colours or hues in full millimetres. If greater precision is required, the original greyscale image is used (Fig. 2) and then any point on the screen can be expressed in pixels. In this case, drawing a graph of the opacity of the consecutive steps permits to calculate intermediate values by extrapolation (Tagger & Katz 2003).

Fourteen materials (Table 1) of different types that have been mentioned in published studies or case reports were gathered from commercial sources for assessing their radiopacity. Gutta-percha cone compound was



**Figure 2** Unretouched radiograph in greyscale reproduction, as scanned. The material is Ketac Silver – 10.5 mm Al. Although the picture appears less clear than the pseudo-colour rendition, it is more precise and contains more detail.

added as a control, although it is sometimes considered a *bona fide* root-end filling material (Marcotte *et al.* 1975). The manufacturers of the test specimens are listed alongside the product in Table 1. The lot or batch number, whenever indicated on the package, is available through the authors. The materials that were tested belong to various groups: temporary or intermediate filling materials, such as Cavit or IRM; Altect, a hard-setting aluminate

base-liner; glass ionomers and composite resins, including compomers like Dyract, etc. (Torabinejad & Pitt Ford 1996). The ethoxy-benzoic acid-based cements constitute a family by themselves, including EBA, supplanted by Super EBA and Superseal cement.

The mineral trioxide aggregate (MTA) assessed was obtained from an experimental batch without additives (by courtesy of the Loma Linda University). Presently, it is available commercially as ProRoot MTA with radiopacifier added, distributed by Dentsply Maillefer (Ballaigues, Switzerland).

The testing procedure followed, in general, the protocol specified by ISO Standard no. 6876. Before exposure, the samples were coded and their identity was kept secret until the end of the measurement stage. A dental X-ray machine (Space Maker 11, S. S. White, Philadelphia, PA, USA) operated at 65 kV and 10 A with a focus to target distance of 30 cm served to expose the films (Kodak Ektaspeed Poly Soft, EP21) for 0.6 s. It should be noted that older versions of the Specification allowed use of D-type film only. The films were developed in GBX processing solutions (Kodak) at constant temperature and time. Using the 'Ready Concept Computerized System' (Redik Co., Haifa, Israel), the radiographs were digitized and evaluated on the screen of a computer. Each sample could be examined with its accompanying step wedge. Three spots were measured in greyscale pixels in every specimen and recorded: (i) a point in the most representative area of the material; (ii) the step (or fraction) with the value closest to that of the sample; and (iii) a point in the background. The latter served to compute the value of the fog and base (and glass carrier) in each film so that it could be subtracted from the pixel values of all readings made on it. The images were examined in pseudo-colour fashion and in greyscale mode.

## Results

The results in pseudo-colour (mode 3) were spectacular and provided immediate visual feedback (Fig. 1), but the greyscale mode (Fig. 2) permitted a precise evaluation in pixels. The readings were tabulated, and a curve of the pixel value of the first 10 steps was drawn (Tagger & Katz 2003). It was almost rectilinear in this area and indicated that extrapolation to within two decimal figures (the second rounded to 0.5) was possible (Table 2). The range of the radiopacity of the materials was very wide – from 1.75 mm Al to over 10 mm Al – yet the majority of the modern root-end filling materials were within the range of 2–6 mm.

**Table 1** Alphabetic list of materials and their manufacturers<sup>a</sup>

| Material                     | Manufacturer                                  |
|------------------------------|---|
| Altect                       | G-C Dental Corp., Tokyo 174, Japan            |
| Amalgam                      | Tylin, Kerr Sybron, Romulus, MI, USA          |
| Cavit G                      | ESPE Seefeld/Oberbay, Germany                 |
| Cavit W                      | ESPE Seefeld/Oberbay, Germany                 |
| Diaket                       | ESPE Seefeld/Oberbay, Germany                 |
| Dyract                       | Dentsply DeFrey, Constance, Germany           |
| Fuji II Glass ionomer cement | G-C Dental Industrial Corp., Tokyo 174, Japan |
| Herculite                    | Kerr Sybron, Romulus, MI 48174, USA           |
| Z100                         | 3M Dental, St Paul, MN, USA                   |
| IRM                          | Caulk/Dentsply, Milford, DE, USA              |
| Ketac Silver                 | ESPE Seefeld/Oberbay, Germany                 |
| MTA                          | Experimental, Loma Linda U, CA, USA           |
| Super EBA                    | Stadent International, Staines, Middlesex, UK |
| Superseal Cement (EBA)       | Ogna Laboratori Farmaceutici, Muggio, Italy   |
| Gutta-percha (control)       | United Dental Manufacturers, FL, USA          |

<sup>a</sup>The batch or lot numbers, whenever available, may be obtained from the authors.

**Table 2** Root-end filling materials and relative radiopacity in mm Al

| Root-end filling material | Relative radiopacity |
|---------------------------|----------------------|
| Altect                    | 1.75                 |
| MTA                       | 1.75                 |
| Fuji glass ionomer        | 2.10                 |
| Dyract                    | 2.40                 |
| Herculite                 | 2.40                 |
| Z 100                     | 3.70                 |
| Cavit G                   | 4.40                 |
| Cavit W                   | 4.55                 |
| Super EBA                 | 4.60                 |
| IRM                       | 5.00                 |
| Superseal EBA             | 5.80                 |
| Ketac Silver              | 10.00                |
| Diaket                    | 11.00                |
| Amalgam (Ag)              | 13.00                |
| Gutta-percha <sup>a</sup> | 7.25                 |

<sup>a</sup>Control.

## Discussion

The results vindicate the apprehension that some of the materials presently used or suggested for root-end (retrograde) fillings are not sufficiently radiopaque, even though the minimal limit of opacity is not known for lack of an appropriate standard. It appears that this limit should be higher than that allowed for intracanal filling materials that are bordered by recognizable dentine (3mm). The results obtained in this study are comparable, within the limits of acceptable experimental error, to those found in other studies (Shah *et al.* 1996). Conversely, Laghios *et al.* (2000) reported much higher values of radiopacity for the same or similar materials. This underlines the importance of including with the experimental group a control with known properties for calibration. Thus, gutta-percha exhibited opacity equivalent to 7.25 mm Al, identical to previously reported values, obtained with the photometric method (Katz *et al.* 1990) and similar to the radiopacity measured by Shah *et al.* (1996).

On the other hand, the great discrepancy between the radiopacity of MTA as reported by Shah *et al.* (1996) and the low opacity exhibited by the sample in this study (6.43 mm Al vs. 1.75 mm Al) is because of the fact that a predistribution experimental batch was assessed, prepared for studying the biological properties. The commercial product 'ProRoot' (Dentsply Maillefer) presently available contains a radiopacifier that was incorporated for clinical use. As at the time this study was carried out the packaging of ProRoot was being modified, we decided not to include it to avoid confusion in case of concomitant change in its composition.

Common composite resins and glass ionomer cements, as well as compomers appear unacceptable for root-end filling from the point of view of radiopacity. However, as they were found quite biocompatible, to the point of serving as a substrate for laying down reparative cementum (Andreasen *et al.* 1993), it is important to find ways to improve their radiopacity as soon as a standard is elaborated. The cements in the EBA group have similar composition, but Superseal is more radiopaque because part of the zinc oxide was replaced with calcium tungstate.

The recommendation that the radiopacity of root-end filling materials should be greater than that of root canal sealers (Shah *et al.* 1996) appears justified. However, the appropriate value (equivalence in mm Al) should be based on evidence from large-scale clinical studies comparing the radiopacity of known materials and taking into account anatomical difficulties, such as thick bony structures in some regions.

In conclusion, a specific standard for root-end (retrograde) filling materials is urgently needed. Substantial data are being gathered presently on some of the properties that are usually covered by international standards, such as: biocompatibility, working time, flow, leakage, solubility, radiopacity, etc. These warrant establishment of appropriate subcommittees and working groups that may initiate and channel the efforts for establishing a comprehensive standard for root-end (retrograde) filling materials.

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