COMPARATIVE RADIOGRAPHIC ASSESSMENT OF A NEW BIOCERAMIC-BASED ROOT CANAL SEALER

DANA HRAB1, ANDREA MARIA CHISNOIU2, MINDRA EUGENIA BADEA3, MARIOARA MOLDOVAN4, RADU MARCEL CHISNOIU1

1Odontology, Endodontics and Oral Pathology Department, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania
2Prosthetic Dentistry Department, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania
3Preventive Dentistry Department, Iuliu Hatieganu University of Medicine and Pharmacy, Cluj-Napoca, Romania
4Polymeric Composite Department, Raluca Ripan Institute for Research in Chemistry, Babes-Bolyai University, Cluj-Napoca, Romania

Abstract

Background and aims. The aim of this study was to assess the radiopacity of two bioceramic-based root canal sealers, the conventional TotalFill BC sealer (FKG Dentaire Switzerland) and a new experimental filling material developed in collaboration with ‘Raluca Ripan’ Institute for Research in Chemistry, Cluj-Napoca.

Methods. Five disc samples were prepared using both materials (10 mm diameter x 1 mm thickness), being subjected to digital radiography together with aluminum step wedges (1 to 12 mm in thickness), in accordance with ISO 6876: 2012. Radiopacity was determined by the computer analysis of the images obtained. Four different areas were selected for each sample, corresponding to a disk-sample quadrant. Statistical analysis was performed using ANOVA.

Results. Both materials showed a radiopacity that was 3 mm greater than the equivalent thickness of aluminum. Total Fill BC showed greater radiopacity than the experimental material, but the differences were not statistically significant.

Conclusions. Both materials comply with ISO 6876: 2012 recommendations on minimum radiopacity.

Keywords: radiopacity, bioceramic materials, root canal sealer, digital radiography, aluminum step wedge

Introduction

Since the first studies on the prognosis of root canal treatments, the quality of the filling material was considered essential to their success [1]. The presence of voids in the filling mass was associated with bacterial proliferation and the development of periapical lesions [2].

Among the most important factors influencing the quality of the treatment are certainly the sealers [3,4,5,6]. These materials should be biocompatible [7,8] and they must have the adequate physicochemical [9,10] and antimicrobial properties [11].

In this context, it is important to study the properties of root canal filling materials in order to determine the optimum parameters for the development of new ones and to evaluate those that are already on the market.

Among other physicochemical properties, the ideal root canal sealer should present sufficient radiopacity to be distinguished from adjacent anatomical structures, such as dental tissue or jaw bone [12,13]. Higginbotham [14] was the first researcher who published a comparative study on the radiopacity of different root canal fillings and gutta-percha cones used in root canal treatment. Eliasson and Haasken [15] have established a comparison standard for radiopacity
studies using optical density values for impression materials and calculating the equivalent thickness of aluminum required to result in similar radiographic density. Beyer-Olsen and Orstavik [16] introduced a comparison standard using an aluminum step wedge with 2-mm increments in thickness to evaluate the radiopacity of root canal sealers.

In 1983, The American National Institute for Standards and Technology (NIST) and The American Dental Association (ADA) issued a series of rules and tests - called Specification no. 57 - to assess the physicochemical properties of root canal sealers in an attempt to standardize their testing and promote quality in dental materials research. This specification was revised in 2000 and includes the following tests: film thickness, setting time, flow, radiopacity, solubility and dimensional change following setting [17].

Due to the diversity of composition of the available sealers and considering the ANSI/ADA standards, the purpose of this study was to evaluate the radiopacity of two bioceramic-based root canal sealers.

**Material and methods**

In this study we evaluated the radiopacity of two bioceramic root canal sealers, one that is already on the market - Total Fill BC sealer (FKG Dentaire Switzerland) and a new experimental filling material developed in collaboration with ‘Raluca Ripan’ Institute for Research in Chemistry, Cluj-Napoca (Table I).

Five disc-shaped samples were prepared from each material (10 mm diameter x 1 mm thickness) according to manufacturers’ instructions. The samples were stored at 37°C and 95% humidity until the final adhesion [18].

Pure aluminum step wedges with a thickness ranging from 1 to 12 mm were used as standards. The purity of the graded standard used in this study, as measured by optical spectroscopy, was 99.52% Al, 0.22% Fe and 0.001% Cu, in accordance with the recommendations in the literature [19].

The discs were placed together with standard aluminum on an in vitro intraoral sensor (Figure 1). Digital radiographic images (Figure 2) were obtained using an XIOS Plus (Sirona) intraoral sensor system and a Soredex (Minray) X-ray unit at 70 kV, 7 mA, 0.32 seconds exposure time at a focal length of 30 cm.

Radiopacity was determined by digitally processing the radiographed discs using a computer application (Figure 3) [20]. Four areas have been selected for each sample, corresponding to a different quadrant (quadrants I, II, III, IV) of the prepared disc. The area of choice involved an area where no air bubbles are present and the homogeneity - determined using the same applications - meets the standard (minimum 30% homogeneity) (Figure 4).

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**Table 1.** Chemical composition of the two materials.

| Sealer                  | Composition                                                                 |
|------------------------|-----------------------------------------------------------------------------|
| Total Fill             | Zirconium oxide (35-45%), tricalcium silicate (20-35%), dicalcium silicate (7-15%), calcium hydroxide (1-4%) |
| Experimental material  | Hydroxyapatite with silver (10-15%), Hydroxyapatite with zinc (5-10%), Zirconium oxide (10-15%), aluminosilicate glasses (45-50%), calcium hydroxide (5-10%) |

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**Figure 1.** Positioning discs and standards on the sensor.  
**Figure 2.** Digital radiographic images of samples and standards.
Statistical interpretation of the results was performed using one-way ANOVA, and the significance level was set at $p \leq 0.05$.

**Results**

Table II shows the radiopacity of the two materials in the four quadrants (I, II, III, IV) of the disc to be sealed. Radiopacity is expressed in terms of equivalent aluminum thicknesses (in millimeters), higher values accounting for higher radiopacity.

The average radiopacity of Total Fill BC sealer is $4 \pm 0.15$, and that of the experimental material is $3.77 \pm 0.27$. Although there were differences between the values determined for the two materials, they were not statistically significant ($p > 0.05$).
Table II. The radiopacity of the two materials.

| Sealer/ Quadrant | Total Fill I | Total Fill II | Total Fill III | Total Fill IV | Exp. mat. I | Exp. mat. II | Exp. mat. III | Exp. mat. IV |
|------------------|--------------|--------------|---------------|--------------|------------|------------|------------|------------|
| Sample 1         | 3.89         | 3.63         | 3.94          | 3.91         | 3.42       | 3.23       | 3.36       | 3.29       |
| Sample 2         | 4.01         | 3.98         | 3.96          | 4.08         | 3.62       | 3.73       | 3.64       | 3.81       |
| Sample 3         | 4.15         | 4.21         | 4.18          | 4.32         | 3.84       | 3.92       | 3.82       | 4.02       |
| Sample 4         | 3.97         | 3.86         | 4.03          | 3.99         | 3.11       | 3.75       | 3.88       | 3.95       |
| Sample 5         | 4.08         | 3.97         | 4.15          | 4.11         | 3.79       | 3.66       | 3.92       | 3.96       |

Discussion

The tightness of root fillings is imperative to maintain the sterile environment obtained from the mechanical and antiseptic treatment of the root canal [21]. The type of filling material may influence the radiographic images of root canal treatment [22].

Radiopacity is a desirable quality of root canal sealers as it allows the estimation of the length, width and the shortcomings that may occur during treatment [22,23]. Using a material with a very high radiopacity may give the false impression of compact filling, despite the presence of voids in its mass. Conversely, a low radiopacity of the material can be interpreted as its absence in areas where it is found in a very small amount.

Conventional radiography and optical densitometry have been usually used in the literature to evaluate the radiopacity of filling materials [16]. The indirect method has also been used in some studies, converting existing radiographs into digital images [24,25]. Meanwhile, the use of digital radiographs has become more popular, as they save time and increase image quality [25].

In this study, digital radiographic images were evaluated using computer software for analyzing and comparing the images obtained. By using digital radiography, it was not necessary to convert conventional film radiographic images or to perform image calibration, since both samples and standards were positioned simultaneously on the intraoral sensor. ISO standards do not mention the use of the indirect or direct method for assessing the radiopacity of dental materials, so this should be taken into account in the future by the International Organization for Standardization [26]. Rasimick et al. [27] have established that the radiographic technique influences radiopacity values of filling materials. Materials containing barium and bismuth may have different radiopacity when using phosphor plates. There can also be differences in aluminum step wedge alloy, shutter speed, focal length, kVp, mAs, all of which influence radiopacity measurements.

According to international standards, the radiopacity of root canal sealing materials should be ≥3 mm equivalent aluminum thickness, although a few filling materials on the market do not comply with this requirement [28]. Some authors have suggested that a value of at least 4 mm equivalent aluminum thickness would be more appropriate [27]. Based on the results obtained in this study, Total Fill presented a radiopacity close in value to that of the experimental material and similar to another bioceramic sealer - Endosequence BC which, according to a study by Candeiro et al. [29], showed a radiopacity of 3.84 mm equivalent aluminium thickness. Considering that the experimental material studied in this paper is a resin-based material, the incorporation of radiopaque agents can easily modify radiopacity, but an increased radiopacity might hide filling mass imperfections, especially when the sealer is used in combination with gutta-percha.

Aoyagi et al. [30] have reported that radiopacity increased with the increase in opaque agent content, as well as with the increase in the atomic number of the element. Chang-Kyu Kim et al. [31] have assumed that the increase in radiopacity of a root canal filling material entails the increase in cytotoxicity, but they haven’t detected any correlation between these two factors. This means that the radiopaque agent is not the only one that is cytotoxic, but other components of the sealers also contribute to its cytotoxicity.

Conclusions

The radiopacity of the materials in this study varied, but the differences were not statistically validated. All values determined were higher than 3 mm aluminium thickness and therefore they have all complied with ISO standards.

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