Sealing ability of two bioceramic sealers used in combination with three obturation techniques

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ABSTRACT

Aim The aim of this study was to evaluate the sealing ability of two bioceramic endodontic sealers when used in combination with three different obturation techniques.
Materials and methods A sample of 100 recently extracted intact human single-rooted anterior teeth was included in the study. After the instrumentation phase, the teeth were randomly divided into five groups and filled with different techniques and materials. Group 1 (n=20) was filled using Thermafil® obturators (Dentsply/Maillefer) with BioRoot™ RCS (Septodont); Group 2 (n=20) was filled using a single GP cone with BioRoot™ RCS (Septodont) bioceramic sealer; Group 3 (n=20) was filled using warm vertical condensation with BioRoot™ RCS (Septodont) bioceramic sealer; Group 4 (n=20) was filled using warm vertical condensation with CeraSeal (Meta Biomed) bioceramic sealer; Group 5 (n=20) was filled with carrier-based obturation (Thermafil®, Dentsply/Maillefer) with CeraSeal (Meta Biomed) bioceramic sealer. Apical leakage was evaluated and statistical analysis was applied (Bonferroni and ANOVA tests) with the significance level set at $P < 0.05$.
Results All groups showed a low amount of apical leakage, without statistically significant differences.
Conclusions Under *in vitro* conditions, the two bioceramic endodontic sealers used in combination with the obturation techniques used, both warm and cold gutta-percha, can similarly seal the root apex.

KEYWORDS Endodontic cements, Bioceramics, Obturation techniques, Warm gutta-percha techniques, Cold gutta-percha techniques.

INTRODUCTION

The role of endodontic sealers is to ensure a proper seal between root dentinal walls and endodontic obturation materials. The sealer should fill tridimensionally the root canal anatomy, penetrating also in lateral and anastomotic canals (1,2).
In the last 30 years, different endodontic sealers were proposed on the market and used by practitioners, such as zirconium oxide, calcium silicates, calcium hydroxide, resin-based et cetera (3-5).
The major function of a root canal sealer is to fill imperfections and increase adaptation of the root filling material to the canal walls, failing which the chances of leakage and failure increase (4-7).
Several obturation techniques are daily used by practitioners and can be divided into two groups as follows.

1. Warm gutta-percha techniques: carrier-based obturation (8,9), continuous-wave of condensation technique, plasticized technique, warm vertical condensation technique (10-14).
2. The cold techniques: lateral compaction, single cone technique (15-19).

The use of bioceramic sealers was originally proposed in combination with the single cone technique (20-21), while more recently they were also used with warm gutta-percha techniques with good results (19, 22-24).
Bioceramic sealers are biocompatible and inorganic materials that include zirconia and alumina, bioactive glass, coatings and composites, hydroxyapatite, and resorbable calcium phosphates (25). Also, new bioceramic cements can be used as substitutes for MTA or as root canal sealers (25). Different bioceramic sealers were recently proposed; those used in this study were the following.

1. Bioceramic sealer BioRoot™ RCS (Septodont) is a sealer based on calcium silicate composition, available in powder-liquid form, and contains zirconium oxide, calcium silicates, calcium phosphate monobasic,

calcium hydroxide, various filling and thickening agents.
2. CeraSeal (Meta Biomed) is a pre-mixed sealer with calcium hydroxide, barium sulfate, zinc oxide, and titanium dioxide zinc striate.

Bioceramic sealers have been reported to induce, *in vitro*, the production of osteogenic and angiogenic growth factors by human periodontal ligament cells (26) and have lower cytotoxicity than other conventional root canal sealers and may induce hard tissue deposition (27,28). Bioceramic sealers also have antimicrobial activity (29). The bioceramic sealers are mainly formed by a powder of tricalcium silicate, zirconium oxide, and povidone while the liquid is an aqueous solution of polycarboxylate and calcium chloride. Bioceramic sealers are inductive materials, this means that during hardening, when they come in contact with tissue fluids, calcium hydroxide reacts with phosphatase enzymes resulting in the formation of hydroxyapatite (30).

Apical leakage is regarded as the most common cause of endodontic failure and is influenced by several variables, such as different obturation techniques, chemical and physical properties of the root canal filling materials, and the presence or absence of the smear layer. This is referred to as primary failure or primary infiltration. However, no obturation technique revealed completely filled root canal systems. Both continuous-wave and carrier-based techniques are based on the concept of minimum sealant interface, whereas the single-cone technique of bioceramic sealant originates from Grossman's concept of the maximum interface of the sealant with the gutta-percha cone intended as support (31).

The aim of the present study was to evaluate the sealing ability of two bioceramic endodontic sealers (BioRoot RCS and CeraSeal) at the apical thirds when used in combination with three different obturation techniques.

The null hypothesis tested was that

1 the two bioceramic endodontic sealers can similarly seal to the apex and
2 bioceramic endodontic cements can similarly seal the apex when used in combination with cold or warm obturation techniques.

MATERIALS AND METHODS

One hundred intact human single-rooted anterior teeth recently extracted for therapeutical reasons were included in the study. After cleaning of remaining tissues, a ×4.5 stereomicroscope (Nikon SMZ645; Nikon, Tokyo, Japan) was employed to rule out any external radicular cracks. Samples were stored in 0.9% saline solution (Salf SPA, Cenate Sotto, Italy) at a temperature of 37°C to prevent dehydration. After preparing the access cavity, pre-curved stainless steel manual K-files # 6, # 8, and # 10 (Sweden & Martina, Italy) were used to define the working length. All the chemo-mechanical preparation procedures of the samples were performed by two calibrated operators (GM, VV). NiTi Mtwo File (Sweden & Martina, Italy) instruments were used for the root canal shaping following the manufacturer's instructions with an endodontic motor (X-Smart™ Plus; Dentsply Maillefer, Switzerland) set at 250 rpm; 2.5 ml of 5% sodium hypochlorite (Niclor 5 dental, Ogna Lab, Italy) was used after each rotary instrument by syringe-needle irrigation with a 31-gauge needle tip. Sodium hypochlorite was preheated to 50° C. Apical patency was maintained by using a # 10 K-type file after each larger file. Once the root canal instrumentation was completed, apical gauging was performed. This technique allows for determining the size of the apical preparation. The final irrigation phase was carried out with 2 ml of 17% EDTA (Ogna Lab, Italy) for 2 minutes, followed by the final rinse with 5 ml of 5% NaOCl for 5 minutes, to optimize the removal of inorganic and organic components. After the instrumentation phase, the canals were dried with paper points.

The teeth, randomly divided into five groups of 20 teeth, were filled with different techniques and materials.

- Group 1 was filled using Thermafil® obturators (Dentsply/Maillefer) with BioRoot™ RCS (Septodont), n=20.
- Group 2 was filled using a Single GP cone with BioRoot™ RCS (Septodont) bioceramic sealer, n=20.
- Group 3 was filled using warm vertical condensation with BioRoot™ RCS (Septodont) bioceramic sealer, n=20.
- Group 4 was filled using warm vertical condensation with CeraSeal (Meta Biomed) bioceramic sealer, n=20.
- Group 5 was filled with Thermafil® obturators (Dentsply/Maillefer) with CeraSeal (Meta Biomed) bioceramic sealer, n=20.

After the root canal obturation, all tooth surfaces were covered with nail varnish;2 mm around the area of the apex of each tooth were left exposed. A diluted ammoniacal silver nitrate solution (1:4 ratio of ammoniacal silver nitrate to distilled water) was prepared, and the diluted solution was filtered with a Millipore filter (0.22-nm filter; Carrigtwohill, Ireland) mounted on a syringe. Under laboratory light, each tooth was placed in a test tube with diluted ammoniacal silver nitrate solution. After 24 h, specimens were rinsed three times in water for 10 min. The nail varnish around the tooth was removed with acetone, and each tooth was placed in a test tube with diluted photo-developer solution (Kodak, Rochester, USA) (1:10 ratio of photo-developer solution to distilled water). After 8 h, teeth were rinsed three times in water for 10 min. Each tooth was embedded in transparent self-curing acrylic resin. The teeth were then sliced with a low-speed diamond saw under water cooling to prevent frictional heat (Isomet; Buehler, Lake Bluff, USA) into two slices along their long axis and perpendicularly to the root.

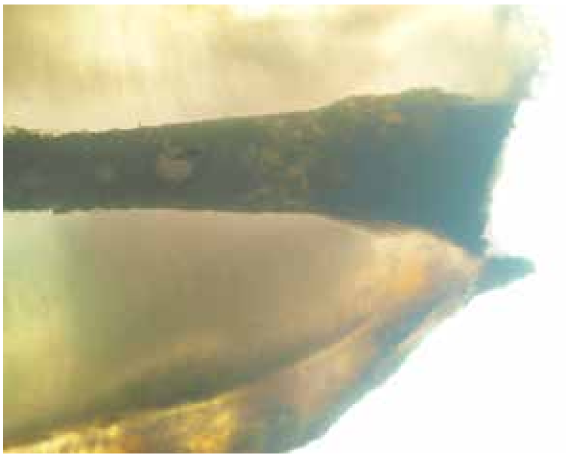

FIG. 1 Apical area of a sample where leakage was evaluated.

Samples were examined with a digital microscope. Two observers (DP, MF) independently scored the amount of tracer along the interface.

The apical leakage was evaluated following the procedure described by Limkangwalmongkol et al (32). In case of a score discrepancy, the sample was evaluated again by the two operators, and a common decision was taken.

The Bonferroni and ANOVA tests were used to assess differences among groups and to separately determine whether leakage significantly differed among groups. The significance level was set at $P < 0.05$, and the analyses were performed with the software package SPSS IBM Statistics version 21 for Mac (SPSS Inc., Chicago, IL, USA).

RESULTS

The apical leakage scores are reported in Table 1.

The average apical leakage of the group of the samples treated with the single cone technique and the BioRoot™ RCS (Septodont) bioceramic endodontic sealer (Group 2) is equal to 0.59 mm (Fig. 3a-c). The same sealer applied with the Thermafil technique (Group 1) reached an average of 0.665 mm, 12.71% more than the previously described technique (Fig. 2). The apical leakage of the groups with vertical condensation and bioceramic sealers (Group 3 and Group 4) was 0.450 mm, the lowest recorded in this study (Fig. 4, 5). In figure 5 it is possible to clearly detect the deep penetration of the bioceramic sealer into the dentinal tubules.

FIG. 2 Group 1 was filled using Thermafil® obturators (Dentsply/Maillefer) with BioRoot™ RCS (Septodont). Good adaptation at the interfaces between root dentin and sealer and sealer and gutta-percha is evident.

	Mean apical leakage (mm)	Standard Deviation
Group 1 (n=20)	0.665 a	0.256
Group 2 (n=20)	0.590 a	0.197
Group 3 (n=20)	0.450 a	0.184
Group 4 (n=20)	0.450 a	0.135
Group 5 (n=20)	0.500 a	0.185

TABLE 1 Apical leakage of the 5 groups. Groups with the same letter did not show statistically significant differences.

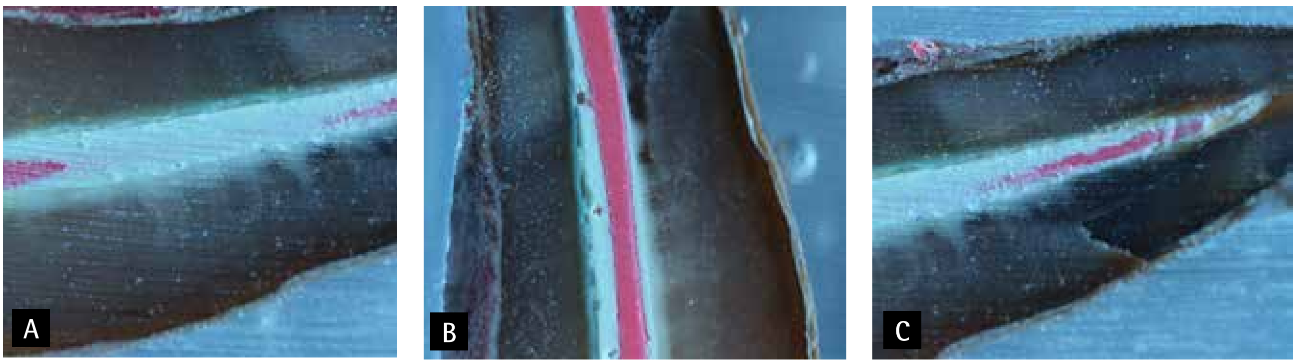

FIG. 3 Group 2 was filled using Single GP cone with BioRoot™ RCS (Septodont) bioceramic sealer.
In figure 3a it is evident that the single cone can fill only partially the root canal and a wide amount of cement is visible. In figure 3b it can be seen that the bioceramic sealer can penetrate into tubular dentin, but also some voids within the cement are visible. In figure 3c the apex is partially visible.

FIG. 4 Group 3 was filled using warm vertical condensation with BioRoot™ RCS (Septodont) bioceramic sealer. Very good adaptation at the apex of gutta-percha and sealer is visible.

FIG. 5 Group 4 was filled using warm vertical condensation with Ceraseal bioceramic sealer: penetration into the dentinal tubules is very well visible.

FIG. 6 Group 5 was filled with Thermafil® Obturators (Dentsply/Maillefer) with Ceraseal bioceramic sealer. Very good adaptation between radicular dentin and sealer and gutta-percha and sealer is evident.

On the other hand, the results of the samples treated with the bioceramic sealer CeraSeal (Meta Biomed) and Thermafil obturation technique (Group 5) showed an average of 0.50 mm (Fig. 6).
However, no statistically significant differences were found among the obturation techniques used. Also, no statistically significant differences were found between the sealing ability of the two types of endodontic cement.

DISCUSSION

In this study, the sealing ability of a bioceramic endodontic sealer (BioRoot™ RCS, Septodont) and another bioceramic sealer (CeraSeal, Meta Biomed) in the apical third of root canals was tested in combination with three obturation techniques. The sealing ability of the new bioceramic endodontic sealers is reported in the most recent literature. Its mechanism is easily explained: tricalcium silicate and dicalcium silicate when hydrated react with water to produce needles of calcium silicate hydrate phase and calcium hydroxide; the latter provides a slowly releasing source of calcium and hydroxyl ions, in the presence of a phosphate-containing fluid, for the precipitation of calcium-deficient apatite via the formation of initial amorphous calcium phosphate (33,34). Also, Yamamoto et al. (35) suggest that all calcium silicate hydrates, when in contact with human fluids containing phosphates, release OH- and Ca2+ ions producing hydroxyapatite. In this study, although root canals were dried with paper points after being cleaned and washed, all samples showed completely set bioceramic sealers: this can be due to the intrinsic humidity of root canal dentin that is sufficient to hydrate the sealer (36). However, to date, bioceramic sealers are considered an advantageous technology in endodontics and they are revolutionizing the former endodontic principles that favored more gutta-percha at the expense of a very thin film of cement (37). Also, the last generation of bioceramic endodontic sealers have great flowability and very small particle size, averaging 0.2 µ, and have hydrophilic properties as well as a low contact angle that allows the sealants to easily spread over the dentinal walls and penetrate into the tubules and irregularities of the root dentin, with the advantage that can improve the mechanical retention of the sealant on the dentinal walls, acting as a physical barrier to prevent microleakage of the root canal system.
The sealing ability of a sealer is linked to its solubility and to its bonding to the gutta-percha cone to the dentin. Several studies have evaluated the sealing abilities of various bioceramic sealers *in vitro* (16-19,26). Regardless of the several methods used, the sealing ability of bioceramic sealers has been found to be satisfactory, and similar to that of other commercially available types of cement. Third-generation bioceramic cements have hydrophilic properties and a low contact angle that allows the sealants to easily spread over the dentinal walls and penetrate into the tubules and irregularities of the root dentin. The penetration of the sealant into the dentinal tubules has the advantage of improving the mechanical retention of the sealant on the dentinal walls. This retention could act as a physical barrier to prevent microleakage of the root canal system (33).
Since both Gade et al. and Pontoriero et al. (19, 38) did not find a significant difference in the quality of obturation when they compared single-cone, lateral condensation, and carrier-based techniques using bioceramic sealers, in this study the single cone obturation technique was used as control. The single cone technique has always been unsuccessful among endodontists because it involves the use of a high amount of cement and it is particularly susceptible to the formation of voids in the canal; recently, with the introduction of bioceramic types of cement, the technique has aroused new interest (39). Also, in favor of cold techniques (40) it was argued that bioceramic types of cement should be used without heat, as this may accelerate the reaction causing an increase in film thickness. In addition, a study (41)

that evaluated push-out bond strength of bioceramic cements when used with warm techniques showed that the bond strength was more favorable in cases where the single cone technique was used compared to thermoplastic techniques. In contrast, another study (42) pointed out that, considering the bond strength alone, bioceramic cements seem to perform better with warm techniques. A systematic review (43) shows that the prevalence of postoperative pain, long-term results, and seal quality of the filling are similar whether a cold or a warm technique is used.

The findings of this study did not show statistically significant differences in the sealing ability of the two types of cement at the apex and consequently the first null hypothesis was accepted. The second null hypothesis tested was also accepted because the two bioceramic endodontic cements showed a similar sealing ability to the apex when used in combination with a cold or/and warm obturation technique.

The results of this study are in agreement with those of another laboratory study (19) that analyzed the sealing ability of several bioceramic sealers used in combination with cold and warm gutta-percha techniques. These findings are in contrast with the belief that chemical changes affect different types of gutta-percha and endodontic sealers during heating, and correlate changes with the heating ability of different heat carriers. It was reported that an increase in the temperature up to 100 °C can cause a degradation of epoxy resin-based sealers and evaporation of water from calcium silicate-based sealers *in vitro*. The duration of heat treatment was also shown to affect the stability of sealers. However, in the root canal, the temperature of endodontic instruments used to apply the gutta-percha can never reach such a high temperature and the heat produced by the tip of the hand instrument can be buffered by dental tissues very quickly. The hot gutta-percha techniques tested in this study were the 'carrier-based' Thermafill and the vertical condensation technique. It can be speculated that the temperature of the gutta-percha in both techniques can decrease quickly into the canal during the time of insertion of the carrier and the hot spreader as well. That might let the bioceramic sealer flow into the root canal and lateral canals as well and seal the dentinal walls without losing its biochemical properties. This speculation is supported by the fact that in this study the bioceramic sealer used inside the root canal was simulating a real clinical situation.

The findings of the present study are in agreement with those of another recent study that investigated the apical sealing ability of a newly introduced bioceramic sealer in combination with continuous-wave condensation technique, single cone technique, and AH plus by means of the continuous wave condensation technique and no significant differences were found in terms of apical seal (43,44). Also, Jeong et al. pointed out that the choice of the obturation technique used with a calcium silicate-based sealer may not necessarily influence sealer penetration in the apical portion of the root canal (45).

This study was performed ex vivo; therefore, in order to confirm or not the findings, and because, to date, there is very little information regarding long-term sealing ability and/or clinical outcomes associated with bioceramic sealers, randomized clinical trials are desirable to clarify the performance of bioceramic materials when used in daily practice. Also, because many of the recently introduced materials are so new, there is not enough evidence yet to support their ability to improve clinical performance. This emphasizes the need to translate anecdotal information into clinically relevant research data on new biomaterials.

CONCLUSIONS

From the findings of this *in vitro* study, the following conclusions can be drawn.

- Under *in vitro* conditions, the two tested bioceramic endodontic sealers can similarly seal the root apex.
- Bioceramic sealers can be used in combination with the obturation techniques used, with both warm and cold gutta-percha.

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