

BioRoot™ RCS

Is a paradigm shift for root canal obturation possible?



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Introduction

The introduction of hydraulic calcium silicate materials for use as root canal sealers was the last development of the original mineral trioxide aggregate (MTA) formulation. The first paper reported the use of MTA as a root canal sealer in conjunction with gutta-percha (1). The use of MTA as a sealer resulted in the formation of mineralised tissues and thus it was the first study to look into the process of biomaterialization and tissue reactions to the MTA and its calcium releasing ability (2). The use of MTA as a sealer resulted in higher leakage apically than gutta-percha obturations (3).

The mechanism of action of MTA and its hydration mechanisms were reported later (4-6) and this was followed by the development of commercial root canal sealers. The first ones on the market were developed in 2008 by Egeo and Angelus (7). At the same time a paper about ProRoot Endo sealer developed by Dentsply was also published (8) but this sealer was not released until recently on the market. The choice of sealers available clinically to date is shown in Table 1. Among these sealers is BioRoot™ RCS developed by Septodont. This article discusses the composition and properties of this sealer.

| Company | Material | Cement type | Radiopacifier | Additives | Vehicle | Presentation | Mixing |
|--|--|---------------------|-----------------------------------|---|------------------|------------------------------------|----------|
| Angelus | MTA Fillapex | Portland cement | bismuth oxide | silicon oxide | salicylate resin | two tubes double barrel syringe | manual |
| Egeo | CPM | | calcium tungstate | | | | |
| Maruchi | Endoseal MTA | | bismuth oxide, barium sulphate | calcium carbonate, propylene glycol alginate, propylene glycol, sodium citrate, calcium chloride | water | powder/liquid | manual |
| Innovative Bioceramix Inc Brasseler FKG | IRoot SP Endosequence BC Totalfill | | bismuth oxide, zirconium oxide | pozzolan | - | syringe | premixed |
| Septodont | BioRoot™ RCS | Tricalcium silicate | zirconium oxide | calcium phosphate | - | syringe | premixed |
| | | | zirconium oxide | water soluble polymer | water | powder/liquid | manual |

Table 1: Choice of commercial tricalcium silicate-based sealers available clinically

Composition

The BioRoot™ RCS is the simplest formulation as shown in Table 1. It is water based and the change from cement to sealer depends on the inclusion of a water soluble polymer that allows material flow. The first use of a water soluble polymer added to Portland cement to improve the material properties was published in 2005 (9). The use of a water soluble polymer to create a root canal sealer was reported in 2009 (10). In this research the various additions of polymer were investigated and their effect on the resultant

material properties and hydration characteristics. The addition of a water-soluble polymer to MTA did not alter the hydration characteristics of the material and resulted in a material with improved properties suitable for use as endodontic sealer cement (10). Furthermore the novel sealer based on MTA demonstrated adequate setting time and was dimensionally stable. It had the potential to be used as root canal sealer cement in clinical practice (11).

The BioRoot™ RCS is presented in a powder



and liquid format as shown in Figure 1. The powder is composed of tricalcium silicate as the active cementitious material and zirconium oxide radiopacifier (12). The liquid is composed of water, calcium chloride, povidone and a water-soluble polymer. The sealer microstructure and elemental analysis is shown in Figure 2 (A, C) and its hydration over a period of 28 days with the formation of the calcium hydroxide is shown in Figure 3. The elemental analysis has been corroborated in another recent study (13). When placed in solution, the sealer leaches high levels of calcium ions when compared to other tricalcium silicate-based sealers such as Endosequence BC sealer and MTA Fillapex (13).



Fig. 1: BioRoot™ RCS presentation by Septodont showing the packaging with the container and scoop for the powder and liquid vials.

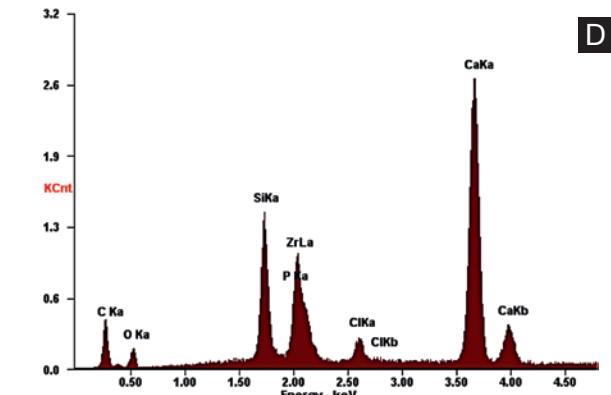
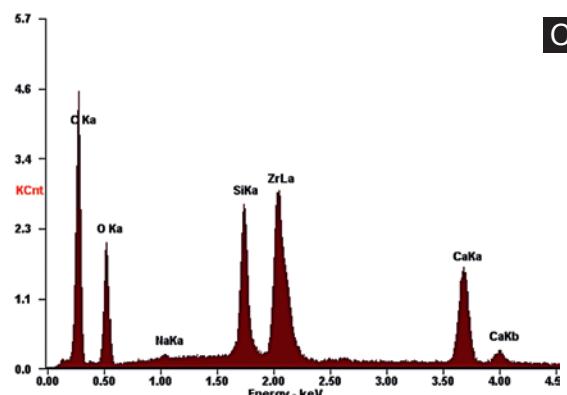
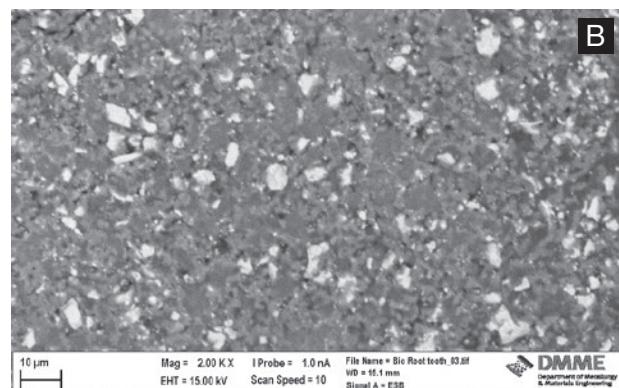
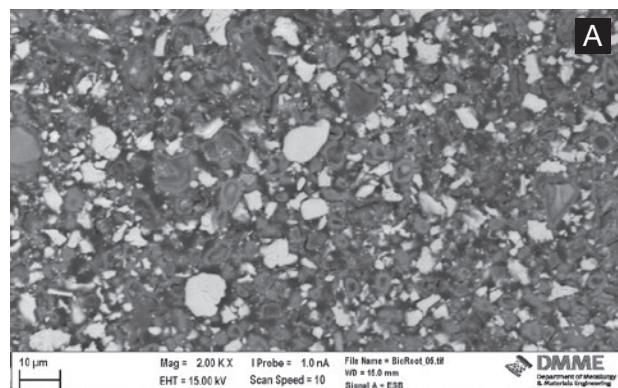


Fig. 2: Surface microstructure of BioRoot™ RCS showing the main phases present and elemental analyses shown in vitro (A, C) and also in contact with the dentine (B, D) indicating chemical changes including the formation phosphates (Reprinted with permission from Xuereb et al. 2015).

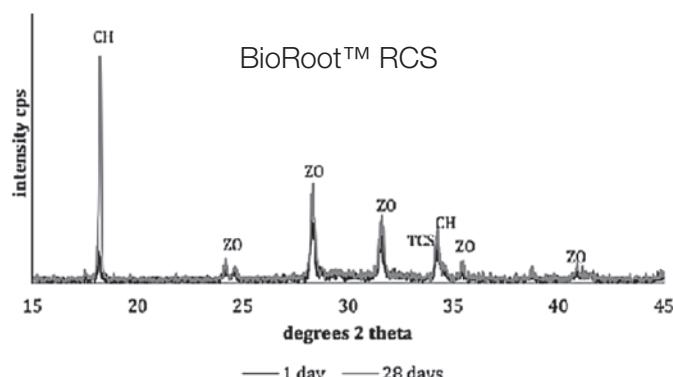


Fig. 3: Hydration of BioRoot™ RCS showing the crystalline phases formed after 1 and 28 days after mixing using X-ray diffractometry (Reprinted with permission from Xuereb et al. 2015).

Properties

Setting time

The final setting time of BioRoot™ RCS was shown to be 324 (± 1) minutes which was shorter than that for AH Plus (15). MTA Fillapex did not set when used as a comparison to other tricalcium silicate-based root canal sealers (14, 15). The setting time of BioRoot™ RCS was reduced drastically on application of heat used in warm vertical compaction obturation techniques (16). The contact with a wet environment lengthened the setting time considerably (14).

In fact the manufacturer recommends the use of BioRoot™ RCS with cold obturation techniques only particularly with gutta-percha in a single cone obturation technique.

Solubility

BioRoot™ RCS was shown to be less soluble than AH Plus and MTA Fillapex immediately after immersion in water but its solubility was higher over time when compared to the resin-based sealers (15). The solubility enhances the biological properties of the sealer. Immersion in phosphate buffered saline improved the BioRoot™ RCS solubility in the long term and a surface precipitate was observed after 14 and 28 days of immersion (15).

Flow and film thickness

BioRoot™ RCS exhibits a lower flow and higher film thickness (12) than the limits specified by ISO 6976;2012 (17) recommendations. The ISO recommendations are intended for inert sealers unlike the BioRoot™ RCS. The flow and film thickness are affected by the heat applied during the warm vertical compaction procedures (16). The manufacturer in fact recommends the use of cold obturation techniques.

Radiopacity

The radiopacity of BioRoot™ RCS was shown to be greater than the lower limit specified by ISO6876;2012 (17) and similar to that of AH Plus and MTA Fillapex (15). The radiopacity was shown to be about 9 mm aluminium thickness

which is similar to Endosequence BC sealer and higher than for MTA Fillapex (14).

Calcium ion release

BioRoot™ RCS was shown to release high levels of calcium in solution, which is much higher than other similar sealer types. In fact it releases double the amount leached by Endosequence BC sealer and ten times as much as calcium ions released by MTA Fillapex for the same time periods under the same conditions (14). Biominerization and the deposition of phosphates over the material when in contact with the dentine has been shown (14) as indicated in Figure 2 (B, D).

Biominerization

Contact of tricalcium silicate-based materials with dentine and tissue fluids has been reported to lead to the deposition of phosphates on the materials surface. This has been extensively described for MTA (18-20). The interaction of dentine and Biodentine™ has been also well documented. A chemical bond is achieved through a mineral infiltration zone at the material to tooth interface (21). This property is important for sealers as bonding of the sealer to the root canal dentine will lead to less microleakage. The mineral infiltration zone has been reported for BioRoot™ RCS using confocal microscopy (22). The mineral infiltration zone and the sealer tags ensure sealer adaption and bonding to the root canal dentine (Figure 4). The tags and mineral rich zone were more evident in the coronal portion than in mid- root and apically. This could be caused by limited action of the ethylene diamine tetracetic acid (EDTA) irrigation and removal of the smear layer further down in the root canal (23). The infiltration of phosphorus into the BioRoot™ RCS when this sealer is in contact with the dentine has not been proven. Surface phase analysis using grazing angle X-Ray diffractometry did not find the formation of calcium phosphate in the material in contact with dentine. This was demonstrated using an in vitro-in vivo model where a low pressure column filled with physiological solution was used to assess

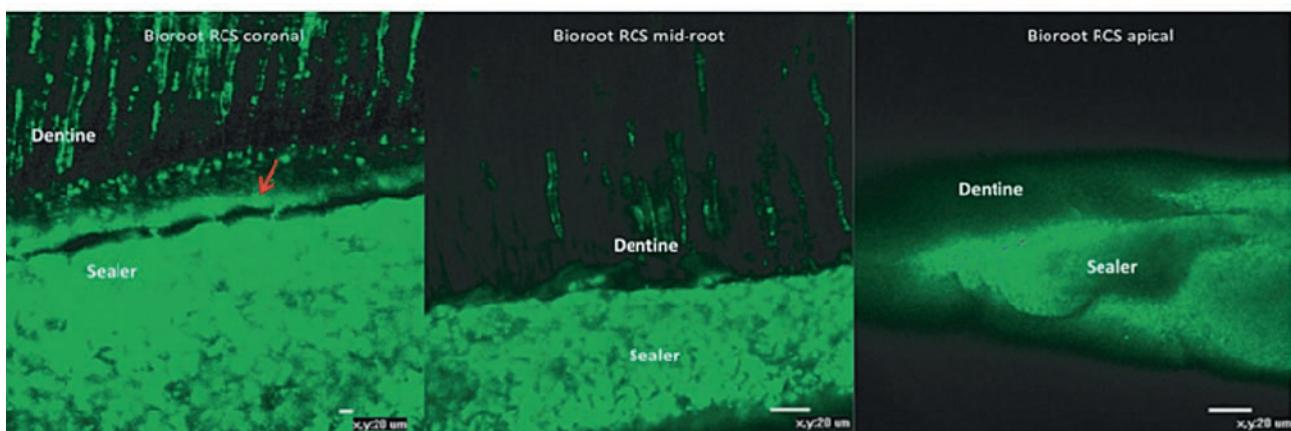


Fig. 4: Confocal microscopic images of BioRoot™ RCS interface with dentine at different levels along the root canal showing the mineral infiltration zone and sealer tags in dentinal tubules (Reprinted with permission from Viapiana et al. 2016).

material setting and the chemical composition when in use. This testing is more reliable than in vitro testing where large volumes of fluid are used which is not a clinically relevant situation (14).

To enhance the bonding of the sealer to root canal wall, a phosphate buffered saline root canal dressing has been suggested (23). This would lead to availability of phosphate ions thus enhancing the bonding at the interface. The deposition of calcium phosphate has been implicated in the increase in push-out bond strength of tricalcium silicate-based root canal sealers (24).

When compared to MTA Fillapex and AH Plus, BioRoot™ RCS showed the greatest antimicrobial activity. The root canal sealers exerted a higher antimicrobial activity when EDTA was used as final irrigant.

Unfortunately the antimicrobial properties of the BioRoot™ RCS and other sealers of related chemistry including AH Plus showed a reduction in antimicrobial properties when phosphate buffered saline was used as the final irrigant during root canal therapy (25).

Biocompatibility

Elutions from BioRoot™ RCS and even direct seeding of cells over the materials showed a high degree of cell proliferation. Migration of periodontal ligament stem cells was observed to be higher with BioRoot™ RCS and the cells maintained their mesenchymal phenotype (26).

This was corroborated by another study testing the elutions from BioRoot™ RCS and other tricalcium silicate-based sealers together with AH Plus. The 1-day material elution showed no cytotoxic effect while 48 and 72 hour extracts exhibited mild cytotoxicity (27). The 1-day elution of BioRoot™ RCS was also evaluated in another study and no DNA double-strand breaks were observed when compared with other resin- and silicate-based root canal sealers (28). BioRoot™ RCS did not compromise the mineralization potential of pulpal A4 stem cells. It was not as cytotoxic as Pulp Canal Sealer which is a zinc oxide eugenol-based material. It did not recruit the pulpal stem cells toward differentiation but preserved their osteo-odontogenic intrinsic properties (29). BioRoot™ RCS also showed less toxic effects on periodontal ligament cells than Pulp Canal Sealer and induced a higher secretion of angiogenic and osteogenic growth factors than Pulp Canal Sealer (30).

Obturation with BioRoot™ RCS

BioRoot™ RCS was affected by the irrigation protocol used. Using EDTA as the final irrigant led to the reduction of calcium releasing ability by half (31). Furthermore in contact with dentine the calcium phosphate phase was not formed when EDTA was used as final irrigant (31) as shown in Figure 5 which compared the crystalline phases formed after using saline or EDTA as the final irrigating solution prior to obturation with BioRoot™ RCS. Irrigation with EDTA showed the highest antimicrobial properties for BioRoot™ RCS. The antimicrobial activity of BioRoot™ RCS was significantly higher than that of MTA Fillapex and AH Plus. BioRoot™ RCS showed the greatest antimicrobial activity and this was enhanced by using EDTA irrigating solution (25). The use of phosphate-rich irrigating solutions is contraindicated with BioRoot™ RCS and all tricalcium silicate-based sealers.

Application of heat during warm vertical compaction affects the flow and film thickness of the BioRoot™ RCS. Thus this sealer is recommended for use with single cone techniques or lateral condensed gutta-percha (16). The choice of sealer should be considered when selecting the obturation technique.

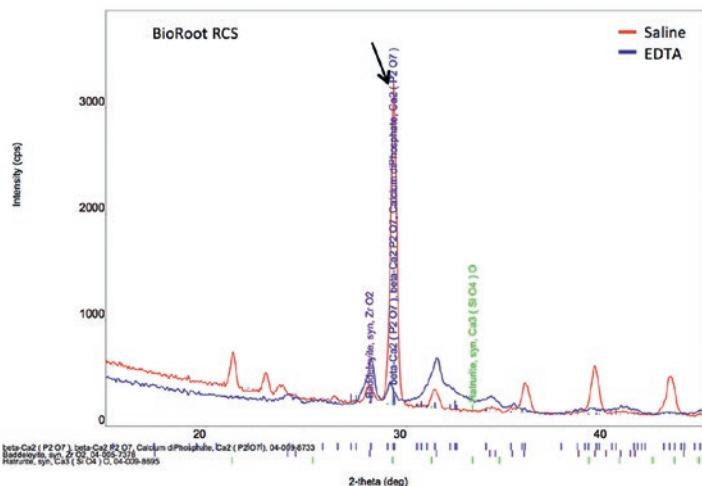


Fig. 5: X-ray diffraction plot of BioRoot™ RCS after contact with dentine irrigated with saline or EDTA showing the depletion of calcium phosphate deposits on the material in contact with the dentine after irrigation with EDTA marked with black arrow (Reprinted with permission from Harik et al. 2016)

The manufacturer recommends the use of single cone obturation technique with BioRoot™ RCS since this sealer is antimicrobial thus its presence would potentially eliminate any microorganisms left inside the root canal space and in the dentinal tubules. Its high antimicrobial activity is evident and it is still effective whatever the irrigating regime used (25).

The retreatability of BioRoot™ RCS sealer used in conjunction with gutta-percha in single cone obturation technique was better compared to AH Plus as less sealer remnants and shorter retreatment times were observed (32).

Conclusion

The BioRoot™ RCS should be used in conjunction with a solid cone in any cold obturation technique. The material solubility enhances the reaction of the material with environmental ionic exchange thus favouring a biological response. The BioRoot™ RCS is highly antimicrobial and the use of EDTA enhances its antimicrobial activity.

This sealer was not developed to conform to the classical recommendations of hermetic seal as it aims to create an environment within the root canal that enhances biological activity and maintains antimicrobial activity. Thus a paradigm shift is possible with BioRoot™ RCS.



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Biography

Professor Josette Camilleri obtained her Bachelor of Dental Surgery and Master of Philosophy in Dental Surgery from the University of Malta. She completed her doctoral degree, supervised by the late Professor Tom Pitt Ford, at Guy's Hospital, King's College London.

She has worked at the Department of Civil and Structural Engineering, Faculty for the Built Environment, University of Malta and at the Department of Restorative Dentistry, Faculty of Dental Surgery, University of Malta. She is currently a senior academic at the School of Dentistry, University of Birmingham, U.K. Her research interests include endodontic materials such as root-end filling materials and root canal sealers, with particular interest in mineral trioxide aggregate, Portland cement hydration and other cementitious materials used as biomaterials and also in the construction industry.

Josette has published over 100 papers in peer-reviewed international journals and her work is cited over 4000 times. She is the Editor of "Mineral trioxide aggregate. From preparation to application" published by Springer in 2014. She is a contributing author to the 7th edition of "Harty's Endodontics in Clinical Practice" (Editor: BS Chong) and "Glass ionomer cements in Dentistry" (Editor: SK Sidhu). She is an international lecturer, a reviewer and a member of the scientific panel of a number of international journals including the Journal of Endodontics, Scientific Reports, Dental Materials, Clinical Oral Investigation, Journal of Dentistry, Acta Odontologica Scandinavica and Acta Biomaterialia.

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