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The single cone obturation technique with a modified warm filler

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The single cone obturation technique with a modified warm filler

Abstract

Objectives: The aim of this study was to develop a new method of obturation by warm sealer in conjunction to single cone gutta-percha and evaluate the suitability of this technique to obturate complex root canal systems.

Methodology: Three root canal sealers namely, AH Plus, BioRoot, GuttaFlow and a prototype sealer composed of tricalcium silicate and 30% zirconium oxide mixed with water and water-soluble polymer were investigated. The sealers were tested for flow, film thickness, setting time and radiopacity following ISO 6876 (2012) recommendations at room temperature and following heat application at 100°C to change the sealer properties. All the test sealers were characterized by scanning electron microscopy and energy dispersive spectroscopy. The volume of voids when used with a single cone obturation technique both unmodified and modified by heat was evaluated using microcomputed tomography.

Results: Although the prototype sealer was designed to be similar to the BioRoot, its physical properties were found to be different. All sealers tested were affected by the heat and exhibited a change in the physical properties mainly the setting time, flow, film thickness and void volume.

Conclusions: The application of heat affected the sealer properties and void volume. The single cone obturation technique may not be suitable for complex canal anatomy and furthermore, AH Plus should not be subjected to high temperatures as its properties deteriorate and void volume increases.

1. Introduction

Root canal obturation is usually performed using a combination of gutta-percha and root canal sealer. For both lateral condensation and warm vertical compaction, the obturation is mostly composed of gutta-percha and the sealer is included to fill the residual spaces within the gutta-percha and between the gutta-percha and the internal walls of the root canal. For both obturation techniques the quantity of sealer is kept to a minimum as the sealer is considered to be the weak component of the obturation. Epoxy-resin-based sealers such as AH Plus (Dentsply) have been used for a number of years in conjunction with both techniques. The irrigation protocol using a final rinse with 17% ethylene diamine tetracetic acid (EDTA) to remove the smear layer thus leaving exposed collagen of the dentine to interact with the epoxy resin of the AH Plus (1, 2) improves the performance of epoxy resin -based sealers. The epoxy resin forms sealer tags thus adhering to the root canal walls (3).

More recently the single cone obturation technique has regained popularity. The ability to prepare the root canal with greater taper instruments and match the final master cone to the size of the master apical file facilitates the use of single cone obturation technique. It is less technique sensitive, requires less armamentarium, easier to perform, cheap and is therefore gaining popularity amongst many dentists. The single cone obturation technique has been suggested for use with hydraulic calcium silicate sealers. These sealers bond to the dentine chemically (3, 4). If the solid cone is matched to the size of the canal preparation it can provide similar obturation quality to the warm vertical compaction (5). Interestingly, dentinal tubule penetration of the sealer occurs independent of which obturation technique is used (6, 7). The single cone obturation technique proportionally will consistent of more sealer than the other techniques; thus the sealer properties are important. A recent study has shown that that sealer properties are more important for elimination of microorganisms than the method of obturation. (8)

Sealer properties are modified by the application of heat (9-12). When heated, hydraulic calcium silicate-based sealers have been shown to exhibit reduced setting time, flow and increased film thickness thus not complying to the ISO 6876; 2012 (13) standards. However, this change in sealer properties may potentially improve the obturation quality since the ISO standards support minimum sealer thickness for standard obturation techniques where the obturation is composed mostly of gutta-percha not sealer. The aim of this study was to investigate the effect of heat on a number of sealers and whether any changes in physical characteristics would enhance the single cone obturation technique.

2. Methodology

The materials assessed in this study included:

- AH Plus (Dentsply International, Addlestone, UK),
- BioRoot RCS (Septodont, Saint-Maur-des-Fossés),
- GuttaFlow (Coltene, Langenau, Germany)
- Prototype - A mixture of tricalcium silicate cement and 30% zirconium oxide mixed with water and a water-soluble polymer (TCS-Zr-30).

Sealers were mixed according to manufacturer's instructions. The prototype sealer was mixed with water and a water-soluble polymer. The water-polymer to powder ratio was determined previously (14). The freshly mixed materials were tested in accordance to the methods outlined by the ISO 6876; 2012 standard for root canal sealers (13) for flow, film thickness, setting time and radiopacity. All testing was performed at room temperature or at 100°C.

2.1 Determination of flow of material

Each material was mixed for 180 seconds (+/- 5 seconds) and 0.05 ml (+/- 0.005) was dispensed on to a glass plate measuring 40 X 40 mm, of 5 mm thickness and a mass of 20 g using a graduated syringe. A second glass plate of the same dimension was placed centrally on top of the sealer and compressed with a mass of 100 g. The maximum and minimum diameter of the compressed sealer discs were measured ten minutes after commencement of mixing. The test was repeated if the two diameters were not within a tolerance of 1 mm of each other. This test was repeated three times for each sample at ambient room temperature and after pre-heating the sample at 100°C in an oven and averages taken.

2.2 Determination of film thickness

The combined thickness of two glass plates, each 5 mm in thickness were measured using a micrometer to an accuracy of 1µm. A portion of sealer was deposited centrally between the two glass plates. After 180 seconds (+/- 5 seconds) from the start of mixing a loading device was used to evenly load 150 N (+/- 3N) vertically on the top plate, so that the sealer completely fills the area between the glass plates. The combined thicknesses of the two glass plates and film of sealer were measured using a micrometer after 10 minutes from the start of mixing. The thickness of the film of sealer was calculated by determining the difference in thickness of plates with and without sealer. The experiment was conducted three times for each sample and a mean value calculated and recorded to the nearest integer.

2.3 Determination of setting time

Sealers were mixed and placed in a mould width and diameter of 10 mm with height of 2 mm, on top of a glass plate approximately 1 mm thick. Moulds were filled to a level surface with sealer and after 120 seconds (+/- 10 seconds) from the end of mixing were placed in a cabinet maintained at 37°C (+/-1°C) and not less than 95% relative humidity (RH). A Gilmore-type metric indenter with a mass of 100 g (+/- 0.5 g) and a flat end of diameter 2.0 mm was lowered vertically on to the horizontal surface of the setting / set sealer at different time points and sealer setting end point was identified once an indentation was no longer visible in the material. The time at which the indentation was not visible was recorded. This was repeated three times and a mean result determined.

2.4 Determination of radiopacity

Sealers were allowed to set in a rubber mould of 10 mm diameter and prepared to a height of approximately 1mm. Specimens were placed next to an aluminium step wedge 50 mm long X 20 mm wide, having a thickness from 0.5 mm to 9.0 mm in equally placed steps of 0.5 mm or 1mm on an intra-oral X-ray occlusal digital film and irradiated at 65 kV (+/- 5 kV) at a distance of 300 mm – 400 mm for sufficient time that the exposed film under the 1 mm thick section of the step wedge has an optical density in the region of 0.5 – 2.5. Image J analysis was used to express the radio-opacity equivalent of the specimens in millimetres of aluminium.

2.5 Characterisation of set sealers

Sealers were placed in rubber moulds and allowed to fully set at 37°C, with tricalcium silicate-based prototype (TCS-Zr-30) and BioRoot allowed to set in humid conditions. Following curing, samples were dried in a vacuum desiccator and then embedded in epoxy resin using vacuum impregnation. The resin blocks were then ground under water using progressively finer grit diamond polishing discs and then polished using polishing cloths and pastes. Prior to examination in the scanning electron microscope, samples were coated with a thin layer of evaporated carbon. Elemental analysis of the samples was also carried out using X-ray energy dispersive analysis.

2.6 Measurement of void volume by microcomputed tomography

The mesial root of a human mandibular molar was prepared using Protaper instruments with the apical portion of the canal being finished with a size F2 instrument (ProTaper Universal, Dentsply, Maillefer, Addlestone, UK). The root with 2 root canals comprising of a buccal and lingual canal with a complete isthmus throughout its length were scanned and plastic blocks were printed with a design to replicate this preparation (15).

A single cone obturation technique was used to obturate each canal, using a 1 ml syringe to inject 0.035 cc/ml of sealer into each canal (0.07 cc/ml total), followed by insertion of a single F2 gutta-percha point (ProTaper Universal, Dentsply Maillefer, Addlestone, UK) into each canal. The obturation process was repeated three times for each sealer, with no addition of heat. The process was then repeated in triplicate by pre-heating each of the sealers at 100°C. The obturated plastic blocks were stored at 37°C at 100% humidity for 24 hours to allow complete set of the sealer before scanning with a high resolution Micro-Computed Tomography (Micro-CT) scanner (Bruker SkyScan1172 micro-CT, Kontich, Belgium) at a voxel size of 13.73 μm. Images were then reconstructed with the

SkyScan reconstruction programme NRecon (Version 1.6.8.0, Bruker, Kontich, Belgium) and beam hardening correction (20) and ring artefact reduction (25%).

Void volume was then determined for each reconstructed obturated block using ImageJ software and voxels were counted using the Voxel Counter plugin. The average of each of the three heated and three unmodified samples for each sealer group was taken. The total canal volume within a plastic block was calculated by Micro-Ct scanning, NRecon reconstruction and image J volume analysis of three non-obturated 3-D printed blocks (Figure 1a). Void volume was then calculated by subtracting the average obturated volume for each sealer from the average non-obturated canal volume.

2.7 Statistical analysis

The statistical analysis was performed using Predictive Analytics Software (PASW) version 18. One-way ANOVA was used to determine whether there were significant differences between data sets. The data was tested to ensure it was normally distributed and then with analysis of variance with P = 0.05 the turkey post hoc test was used. The Least Significant Difference (LSD) test was used to analyse the significance of void volume between the different sealer groups ($p \leq 0.05$), whilst the t-test was used to determine the significance of heating on void volume for each individual sealer group ($p \leq 0.05$).

3. Results

3.1 Determination of flow of material

The flow properties of the sealers are shown in Table 1. All sealers complied to ISO 6876;2012 (13) and exhibited a diameter of flow of not less than 17 mm. Heating the sealers at 100°C increased the diameter of flow for AH Plus ($p = 0$) and TCS-Zr-30 ($p = 0.02$). The TCS-Zr-30 showed a tendency for flocculation. Diameter of flow decreased upon heating for BioRoot ($p = 0$) and GuttaFlow ($p = 0$).

3.2 Film Thickness

Film thickness of tested sealers is shown in Table 1. All the sealers were stable and no difference was shown in film thickness after heat application, with the exception of BioRoot ($p = 0$). It can also be noted that the ISO 6876;2012 (13) standard states that sealers should have a film thickness of not more than 50 µm, and at room temperature only GuttaFlow and the experimental sealer TCS-Zr-30 fulfilled this.

3.3 Setting time

Table 1 shows the setting times for the tested sealers. The application of heat resulted in a reduction in the time taken for the sealers to set for all sealers which was statistically significant ($p = 0$). The greatest decrease in time taken to set was observed in AH Plus, which took 20.08 hours to set at room temperature, but only 10.72 hours following heat application.

3.4 Radiopacity

All the sealers tested had a radiopacity which was in accordance to ISO 6876;2012 (13) thus not less than 3 mm aluminium thickness as shown in Table 1.

3.5 Sealer characterization

The scanning electron micrographs and EDS analyses are shown in Figures 2a and 2b respectively. AH plus was composed of a number of larger particles of calcium and tungsten and smaller particles of zirconium interspersed within a cement matrix. EDS analysis also showed small peaks for carbon and oxygen indicating the presence of an organic phase. BioRoot was composed of calcium rich particles with reaction rims around them. The EDS analysis showed high peaks for calcium, zirconium, silicon and chlorine. GuttaFlow had a more diverse microstructure composed of a number of different particles. EDS analysis revealed peaks for zirconium, zinc, oxygen, silicon and calcium. GuttaFlow is marketed as having combined sealer and gutta-percha in powder form which explains the presence of zinc and oxygen. It is also silicon based and includes the addition of bioglass. Although the prototype sealer TCS-Zr-30 was similar to BioRoot and composed of mainly cement particles with smaller radiopacifier particles interspersed through the matrix, the cement particles did not show well circumscribed reaction rims around them. There was also more radiopacifier present in the matrix when compared to BioRoot. EDS analysis showed peaks for zirconium, calcium, silicon, oxygen, calcium and carbon.

3.6 Measurement of void volume by microcomputed tomography

Void volume percentages for the sealers are shown in Table 1, while composite 3-D images (created in ImageJ) of each obturation are shown in Figure 1b. AH Plus had a lower void volume than the rest of the sealers when it was used without the application of heat ($p \leq 0.05$). The void volume increased significantly when the sealer was heated (+4.23%), compared to the unmodified sealer ($p \leq 0.05$), whilst BioRoot RCS and GuttaFlow exhibited minimal increases in void volume on heating (+0.63% and +0.88% respectively) which was not statistically significant ($p \leq 0.05$). The heated prototype sealer TCS-Zr-30 did not yield any results, as the material became too viscous on heating and thus could not be syringed into the 3-D printed blocks. There was a generalised distribution of voids within the isthmus (Figure 1b (D-H)) for all sealers, with the exception of AH plus which was observed to have voids more concentrated within the coronal region of the isthmus (Figure 1b (B-C)).

4. Discussion

The current study investigates the effectiveness of single cone obturation technique using three sealer types. Due to due natural variation and the abstract shape of the root canal system the use of a single cone, albeit it tapered and designed to fit the final canal preparation is likely to leave significant space for sealer compared to a compacted technique. Therefore, sealer properties are even more crucial with this obturation technique. The single cone obturation has been suggested for use with hydraulic calcium silicate-based sealers and it was comparable to warm vertical compaction (5) and showed dentinal tubule penetration of the sealer (6, 7). It thus presents as an attractive alternative to warm vertical compaction, with the advantage of being quicker and not requiring extra armamentarium.

Most sealers currently available are marketed showing compliance to ISO 6876;2012 (13). This standard is based on the application of the sealer in thin sections and the obturation predominantly composed of gutta-percha. The hydraulic calcium silicate-based sealers do not comply to this standard as these materials change their properties when wet (16). The application of heat during warm vertical compaction changes the sealer properties and therefore this research evaluated three commercial sealers with different compositions.

AH Plus is an epoxy-resin based sealer and when heated it exhibits chemical changes with decomposition of the N-H bonds, severe decrease in setting time and strength (10), increased flow and increased film thickness (11). This is in accordance with the results of this study, except for the film thickness which was shown to be reduced.

Although BioRoot does not undergo chemical changes when heated, the physical properties change (10) which was also shown in the current study. The changes to the physical properties are attributed to the loss of water for the sealer, since the BioRoot is water-based. A prototype sealer was also tested in this study, to be able to monitor the effect of the individual components and how the sealer reacted to the heat. Although the prototype sealer was similar in composition to the BioRoot, it was less affected by the heat applied in relation to flow, film thickness and setting time. The prototype material had a longer setting time and the hydration was not as fast as the BioRoot. This is evident by the lack of reaction rims in the prototype material which were shown in BioRoot, although the materials were aged similarly. The BioRoot contains the addition of a chloride accelerator; the presence of the chloride ion was shown in the EDS analysis (Figure 2b). There was no accelerator added to the prototype material and this helped with its heat resistance.

GuttaFlow is a based on polyvinyl siloxane and contains gutta-percha and a bioglass. GuttaFlow was shown to be bioactive (17). The film thickness increased considerably, flow was reduced when the GuttaFlow was subjected to the heat. There is currently no research on the effect of heat on this material.

The heat applied to the sealers was 100°C for 2 minutes. This setting was done arbitrarily as this is the first study to use heat to modify the sealer properties. It is known that when using heat carriers that are set at 200-250°C, the temperature never rises more than to 100°C (9, 10, 18). Clinically the sealer can be heated using the heat carriers. A heating cycle of 2 minutes was used to ensure thorough heating of the sealer and ensuring that the properties are modified. Previous studies have already been conducted on the effect of heat employed for 2 minutes (9-11).

The adequacy of obturation was assessed by measuring void volume by microcomputed tomography. This is a well-established technique to assess the quality of obturation (3, 5, 19-21). 3-D printed blocks were used to reduce the sample variability and furthermore the blocks were printed from a replica of a natural pre-prepared mesio-buccal root of a lower molar. The root had both MB and ML with complete isthmuses recreating complex anatomy accounted in the clinical situation. They were prepared to a standard size and a matched gutta-percha cone was used for the obturation. This procedure led to more standardization and consistency of the sample groups.

Obturation of complex anatomy is challenging with single cone obturation techniques. None of the sealer groups completely obturated the isthmuses, even without heat application. The lowest void volume was exhibited by the unmodified AH Plus. This increased considerably when the AH Plus was heated indicating that AH Plus should not be heated as already suggested in previous literature (9-12). The GuttaFlow and BioRoot were not affected by the heat and thus the quality of obturation did not deteriorate when they were heated. In previous studies, GuttaFlow was shown to exhibit better marginal adaptation than AH Plus, both at the sealer to core interface and at the dentine to sealer interface at the apical third (22, 23). Although marginal adaptation and void volume are both indicators of adequacy of obturation, the techniques cannot be correlated as indicated in a previous study comparing three methods of assessing root canal obturation (3).

Although the prototype material was similar to the BioRoot, the heating affected its injectability considerably. This may be attributed to the resemblance of the prototype sealer to a non-Newtonian fluid. The application of pressure via the syringe plunger caused an increase in viscosity, resulting in difficulty in obturation of the plastic blocks. Additionally, once force was removed, the sealer showed significantly reduced viscosity, and started to exude out of the apical foramen; resulting in a significantly larger void volume in comparison to the other sealers.

5. Conclusions

Preheating of the sealer used in conjunction with single cone obturation technique could be developed further with the use of appropriate sealers for this specific technique. The application of heat modifies the sealer properties and this could be used to enhance the quality of the obturation.

Declaration

The authors declare no conflict of interest

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Table 1: Mean ± Standard deviations for sealer properties at room temperature (Unmodified) and after application of heat for 2 mins at 100°C (Modified by heat)

Sealer	Radiopacity mm Al	Flow		Film thickness (µm)		Setting time (hours)		Void volume (%)	
		Unmodified	Modified by heat	Unmodified	Modified by heat	Unmodified	Modified by heat	Unmodified	Modified by heat
AH Plus	11.1 ± 0.17	18.1 ± 0.14^{a}	23.9 ± 0.52^{a}	51.7 ± 7.23	43.0 ± 2.65	20.1 ± 0.00^{c}	10.7 ± 0.01^{c}	3.2~~2~~ ± 0.69$^{d\,1}$	7.4~~5~~ ± 4.32^{d}
BioRoot	2.9 ± 0.31	21.9 ± 0.22^{a}	15.1 ± 0.65^{a}	69.7 ± 24.17^{b}	215.3 ± 59.48^{b}	1.5 ± 0.02^{c}	0.5 ± 0.02^{c}	7.3~~3~~ ± 2.66^{1}	7.9~~6~~ ± 3.97
GuttaFlow	3.6 ± 0.07	19.2 ± 0.65^{a}	17.2 ± 0.16^{a}	45.3 ± 1.53	71.7 ± 6.66	0.4 ± 0.01^{c}	0.2 ± 0.00^{c}	6.2~~3~~ ± 1.07^{1}	7.1~~1~~ ± 0.54
TCS-Zr-30	3.3 ± 0.34	17.2 ± 0.14^{a}	18.6 ± 0.36^{a}	44.7 ± 3.21	57.7 ± 2.52	2.4 ± 0.03^{c}	1.8 ± 0.01^{c}	19.8~~4~~ ± 17.28^{1}	N/A
ISO 6876 (2012)	> 3 mm Al	< 17 mm	/	> 50 µm	/	/	/	/	/

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Note: Letters read horizontally show statistical differences on application of heat. Numbers read vertically show statistical differences between sealers

Figure

(A)
(B)
(C)

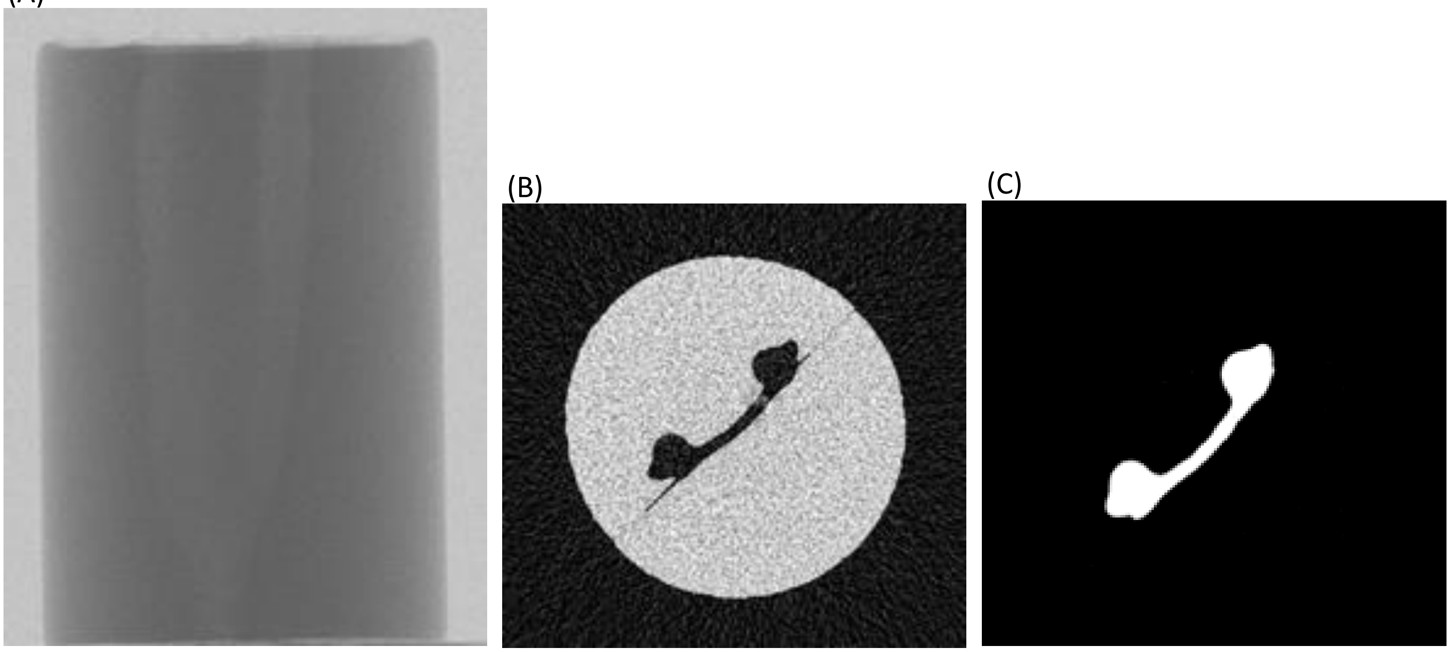

Figure 1a: (A) Micro-CT scanning of non-obturated 3D printed plastic block, (B) NRecon reconstructed slide of non-obturated 3D printed plastic block, (C) Extraction of canal volume of 3D printed plastic block using Image J software. Canals connected by complete isthmus seen.

Figure

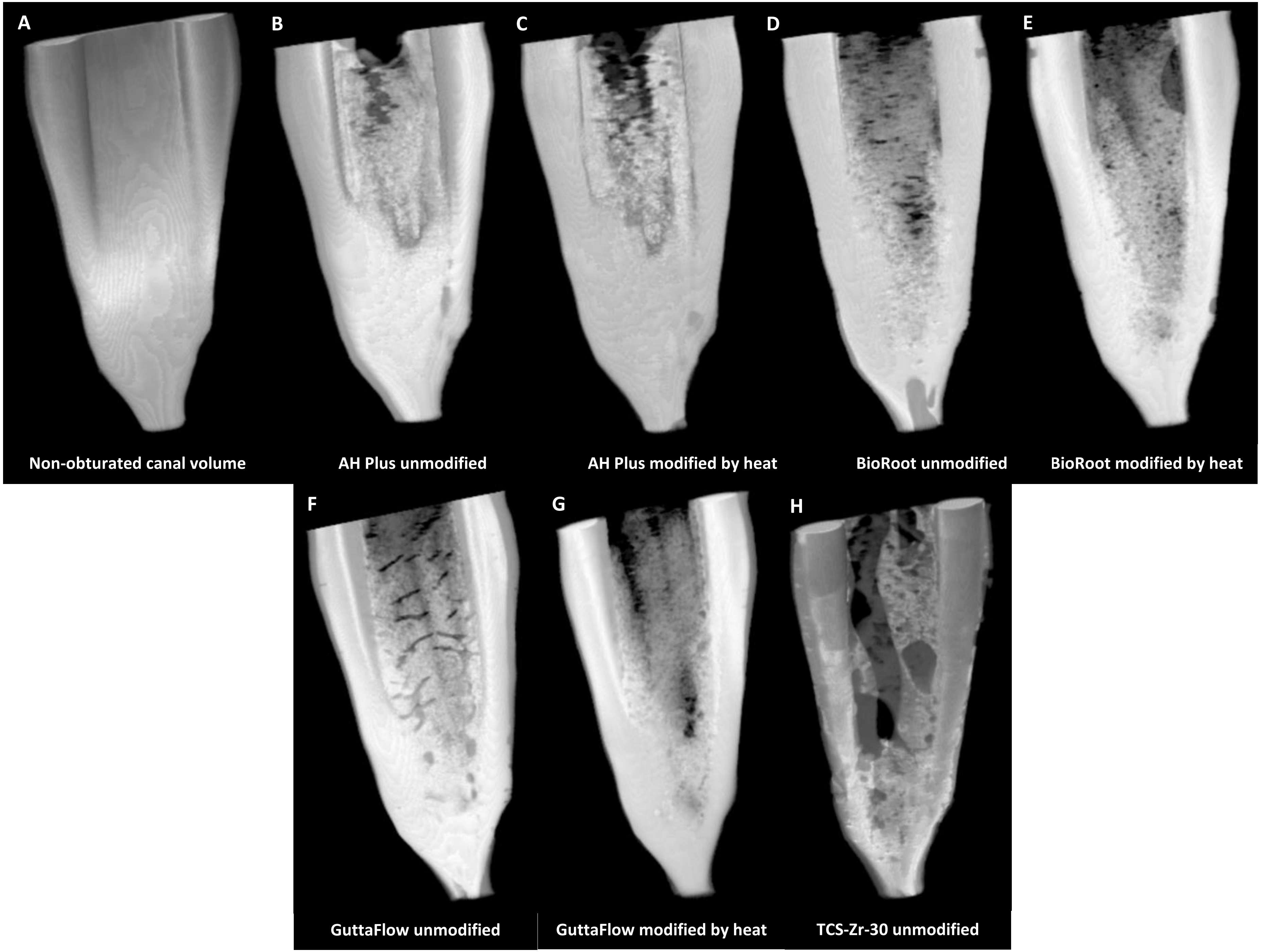

Figure 1b: Composite 3-D images of (A) average non-obturated canal volume and (B-H) average sealer volumes when unmodified and modified by heat

Figure

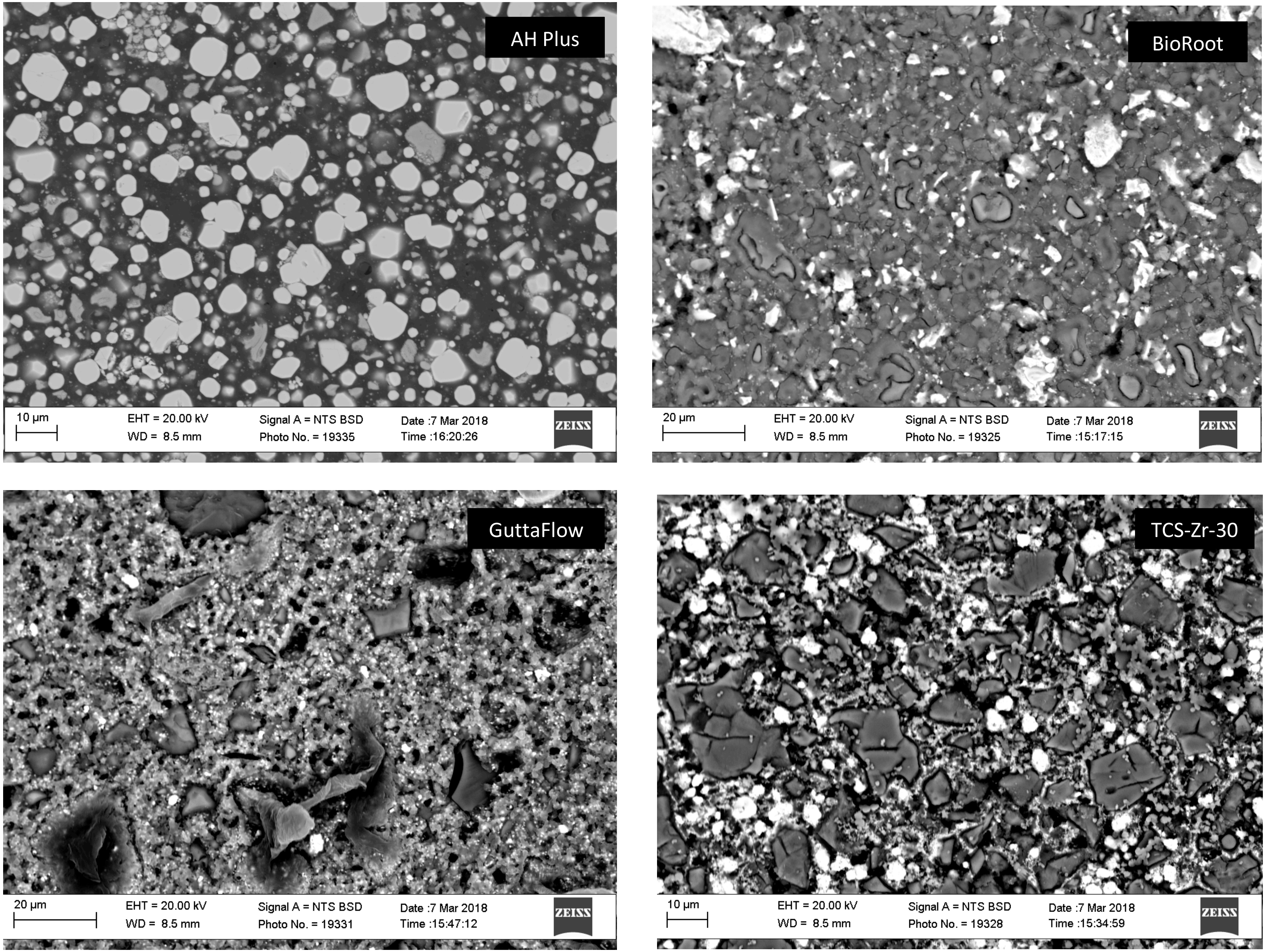

Figure 2a: Back scatter scanning electron micrographs showing sealer microstructural properties (Mag: 2K X)

Figure

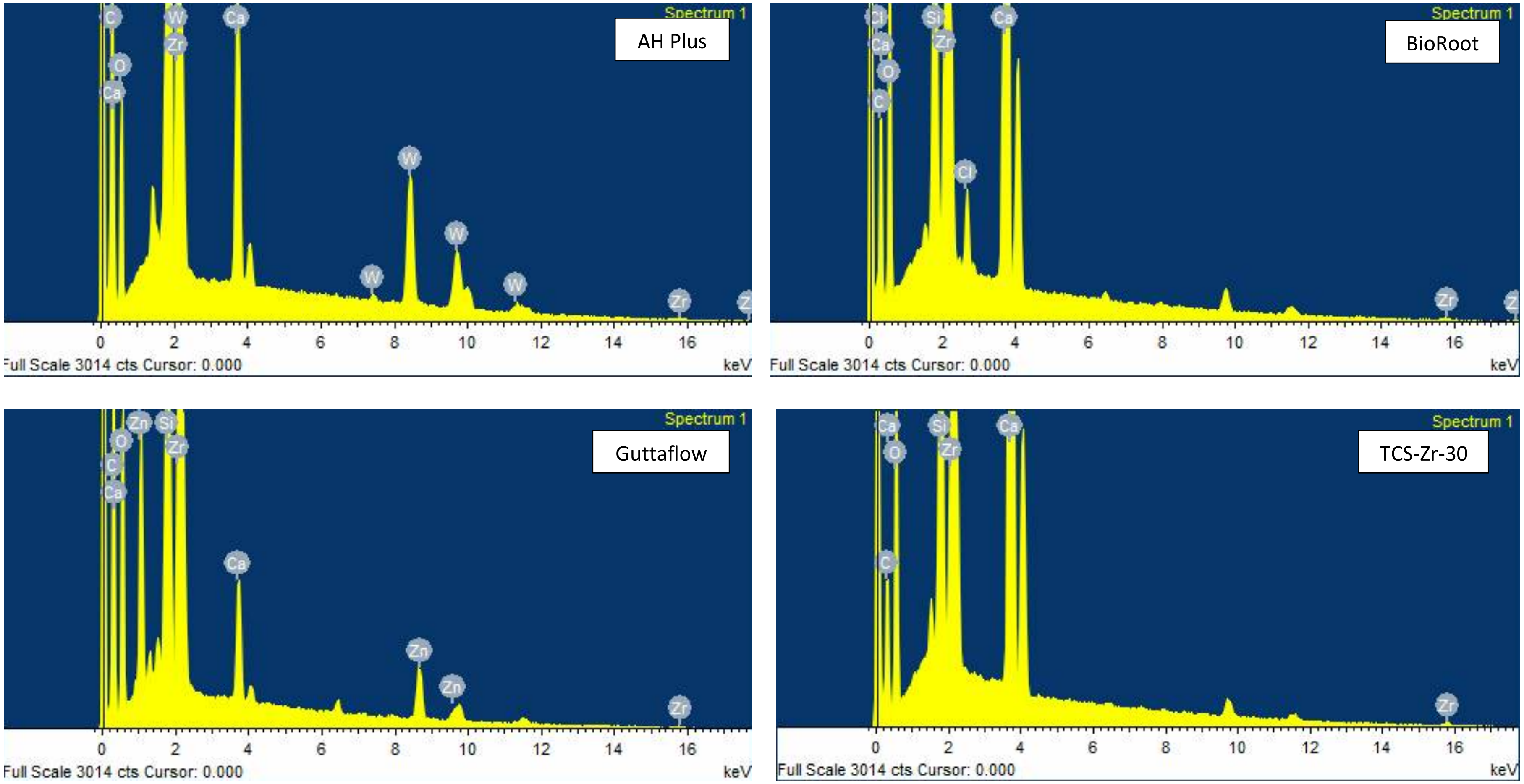

Figure 2b: Energy dispersive spectroscopy plots of sealers showign their elemental composition

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Conflict of interest statement

The authors declare no conflict of interest