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Micro-CT Evaluation of EndoSequence BC Sealer HiFlow Performance by Technique

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Abstract

Objective: Bioceramic sealers have demonstrated many qualities requisite of an ideal sealer outlined by Grossman. Biocompatibility, radiopacity, and antimicrobial properties are some of the qualities that have increased the sealer's widespread demand and use. EndoSequence® BC Sealer HiFlow™ is advocated for use in both the single cone (SC) and warm vertical compaction (WVC) techniques. The aim of this study was to compare the obturation quality of the two techniques with EndoSequence® BC Sealer HiFlow™ in the apical 6 mm of obturated root canals, using micro-CT evaluation of the relationship between the sealer, gutta-percha, and canal wall.

Methods: Two groups (n=10) of extracted human teeth with straight, single canals were used. All teeth were shaped with progressive taper EndoSequence® ESR™ file system to size #45 and irrigated with 6% NaOCl and 17% EDTA. The samples were randomly assigned to one of two groups, differentiated by obturation technique: single cone or WVC. each group and obturated by either SC or WVC. Sealer was applied according to the manufacturer's instructions, canals obturated, and accesses sealed. Teeth were stored at 37° C for 72 hours, allowing for the sealer to set. Micro-CT evaluation was completed to quantify voids within the sealer. Groups were compared utilizing the Mann-Whitney U test.

Results No statistically significant difference in percentage of open porosity was observed when comparing the SC (1.47%) and WV (1.63%) groups.

Conclusions: Within the limitations of this study, micro-CT imaging and volumetric analysis shows both techniques produced statistically similar performance relating to open porosity but neither were able to produce a void-free obturation.

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Introduction and Background

The success of root canal therapy is significantly impacted by the endodontic sealer's ability to provide a hermetic seal [1-2]. Microleakage between the gutta-percha (GP) and sealer, between the sealer and dentin, or through voids within the sealer has been shown to be one of the major causes of endodontic failure[3]. The apical segment of the root canal system is highly variable and a high quality obturation in this area is paramount to a successful outcome[4]. Obtaining a hermetic seal is imperative in the apical segment[2], as this area is prone to bacterial invasion and contamination[5-6]. Premixed calcium silicate endodontic sealers have been introduced into the market for their biological advantages, mainly their bioactivity as described by Almeida et al and dimensional stability[7].

Calcium silicates are bioceramic sealers that have antimicrobial properties[7] and slight expansion upon setting[8]. EndoSequence BC Sealer HiFlow (HF) (Brasseler USA, Savannah, GA) is an updated formulation from the original BC Sealer. The manufacturer states HF has a reduced particle size for improved flow, higher concentration of zirconium oxide to increase radiopacity and maintains a lower viscosity when heated to accommodate warm vertical (WV) techniques in addition to the single-cone (SC) technique. When a matched GP cone is utilized HF and advanced apically, the manufacturer states hydraulic forces distribute the sealer around the cone with minimal introduction of porosity. HF, when utilized in a WV technique, may have the ability to provide additional displacement of sealer into canal fins and isthmuses filled by GP in the traditional warm vertical technique.

Microcomputed tomography (micro-CT) is a non-destructive 3-dimensional radiographic evaluation which allows for the assessment of material differences based on changes in radiodensity. This allows for quantification of areas of dentin, sealer, GP and porosity[9]. Micro-leakage demonstrated by Ricucci et al[10] shows bacteria can penetrate dentinal tubules from loss of seal integrity. There are no studies investigating HF performance in different obturation techniques. This study was designed to compare the sealer porosity produced in root canal obturation by (micro-CT) analysis utilizing HF in the SC and WV techniques. There are no studies

investigating HF performance in different obturation techniques. The aim of this study was to compare the volume of porosity created in the SC and WV techniques utilizing HF by micro-CT evaluation. The null-hypothesis is there will be no difference between the groups related to open porosity.

Materials and Methods

- Sample Selection and Preparation

This vitro model design utilized 20 freshly extracted human canines and premolars with single systems, with mature apex free from fracture, resorption or root surface caries. Each sample was stored in 0.1% thymol solution until initiation of protocol, radiographed in a mesio-distal aspect to verify single-canal system and clean of soft tissue. Hank's Balanced Salt Solution was utilized as a 72-hour presoak at 37° C to simulate physiologic dentin hydration. Next, the samples were decononated to a standardized length of 17 mm from anatomical apex and accessed with 330 carbide bur. Samples were randomly assigned a number 1-20, which was etched on the coronal root surface. Working length was determined as 1 mm short of when a 0.02 taper #10 stainless steel K-file was visualized at the apex and glidepath secured with a #15 K-file to established WL. All samples were shaped with the EndoSequence Reciprocating Files System (Brasseler USA, Savannah, GA) to size large (#45 apical preparation size). Each canal was irrigated with 2 mL 6% NaOCl (Vista Dental) between each file of instrumentation. Smear layer was completed by alternating 2 mL 17% EDTA (Vista Dental) and 2 mL 6% NaOCl. Irritants were delivered via a 30-G side-vented syringe set 1 mm short of the working length. Samples were stored according to group (SC: 1-10 and WV: 11-20 WV) in HBSS 100% humidity at 37° until the obturation phase. Just prior to obturation, each sample was rinsed with 1 mL 6% NaOCL and dried with sterile paper points.

- Sample Obturation

All samples were obturated with size Large ESR Bioceramic gutta-percha points (Brasseler USA). The heat source was an Elements Downpack unit (Kerr) fitted with a 0.06 Fine System B tip (Obtura Spartan Endodontics) and backfilling was achieved using a HotShot backfill unit (Discus Dental) loaded with BC Pellets (Brasseler USA); both units set to 150° C. Prior to obturation, each

sample was radiographed to ensure cone placement was consistent with the master apical file length.

1. Single-Cone: The EndoSequence BC Sealer HiFlow clear tip was inserted into coronal 1/3rd of the canal and slowly dispensed sealer to the level of the orifice. A #10 K-file was inserted to WL to distribute sealer. The GP point was dipped into the sealer, placed into the canal and slowly advanced to WL. The GP cone was seared off 1-2 mm below the orifice with the heat source and gently compacted with a cold #7 plugger.
2. Warm-Vertical: The EndoSequence BC Sealer HiFlow clear tip was inserted into coronal 1/3rd of the canal and slowly dispensed sealer to the level of the orifice. A #10 K-file was inserted to WL to distribute sealer. The GP point was dipped into the sealer, placed into the canal and slowly advanced to WL. The GP cone was seared off at the level of the orifice with the heat source. Next the heat tip was activated and gently advanced 3 mm from WL and compacted with a cold #5. Sealer was placed on the #5 plugger to recoat the canal walls and backfill was completed in 3-4 mm increments 1-2 mm from the level of the orifice.

After completion of obturation, the access of all samples sealed with with a resin modified glass ionomer cement (VitreBond Plus, 3M) and were stored in 100% humidity with HBSS, at 37° C, for 72 hours for sealer setting.

Micro-computed Tomography Evaluation

Each sample was wrapped with tissue paper moistened with HBSS and wrapped with paraffin to maintain hydration during scanning. Samples were placed into a custom a polystyrene form, centered and mounted on the specimen turntable of a SkyScan 1172 (Bruker micro-CT Kontich, Belgium) micro-CT scanner. The apical 6 mm segment was imaged with a 0.25 mm-thick aluminum/copper filter, a spatial resolution of 4.94 µm voxel at 100 kV and 100 mA, 360° rotational angle and 0.2° rotation step. Each sample averaged 5 hours and 34 seconds scan-time yielding 1800 high-resolution images per sample. Beam hardening correction and a ring artifact reduction were used during reconstruction. The acquired projection images were reconstructed into cross-sectional slices with NRecon software (Bruker micro-CT)

The canal, obturation material and porosity was calculated in CTAn software (Bruker micro-CT) by a custom 15-step algorithm developed collaboration with a Micro Photonics software engineer. The percentage of porosity in the total obturation material was evaluated from the working length to the 6-mm level of each root by selecting a volume of interest (VOI, canal volume). The volume as a percentage of total canal, obturations material (gutta-percha and sealer) and porosity (internal and external) was calculated. Closed porosity is a void entirely contained within the obturation material whereas open porosity is a void exposed to the canal wall dentin.

Statistical Analysis

Statistical analysis was performed using SPSS version 22 Software (IBM SPSS Inc, Chicago, IL) at a 95% confidence level (P= .05). The data did not show a normal distribution (% open porosity), and the Mann-Whitney U test for nonparametric data was used for group segment comparison.

Results

There were no significant differences between the group segments related to open porosity (Table 1). Segmental analysis by discrimination of grayscale values was used to determine root structure, filling material and porosity (open and closed) in all samples (0-3 mm and 0-6 mm) by the custom processing algorithm. Open porosity averages were as follows: SC group, 0-3 mm and 0-6 mm segments was 1.51% and 1.47% respectively; WO group, 0-3 mm and 0-6 mm segments was 1.73% and 1.63% respectively. (Table 2)

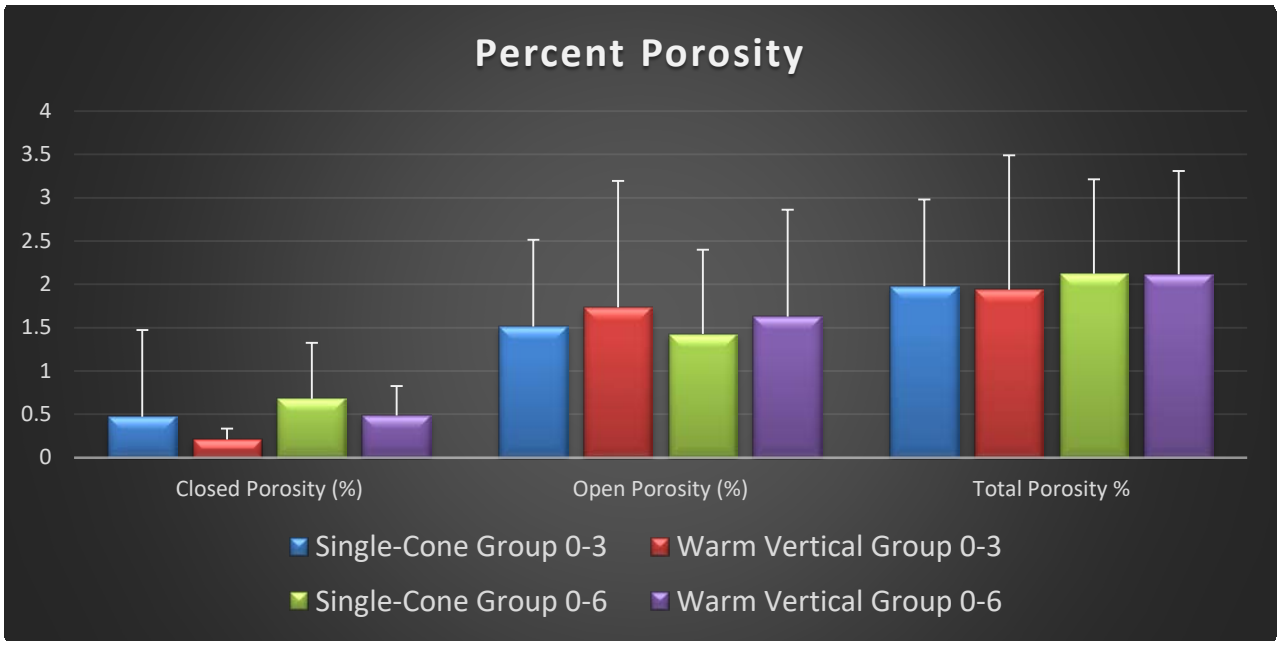

Table 1

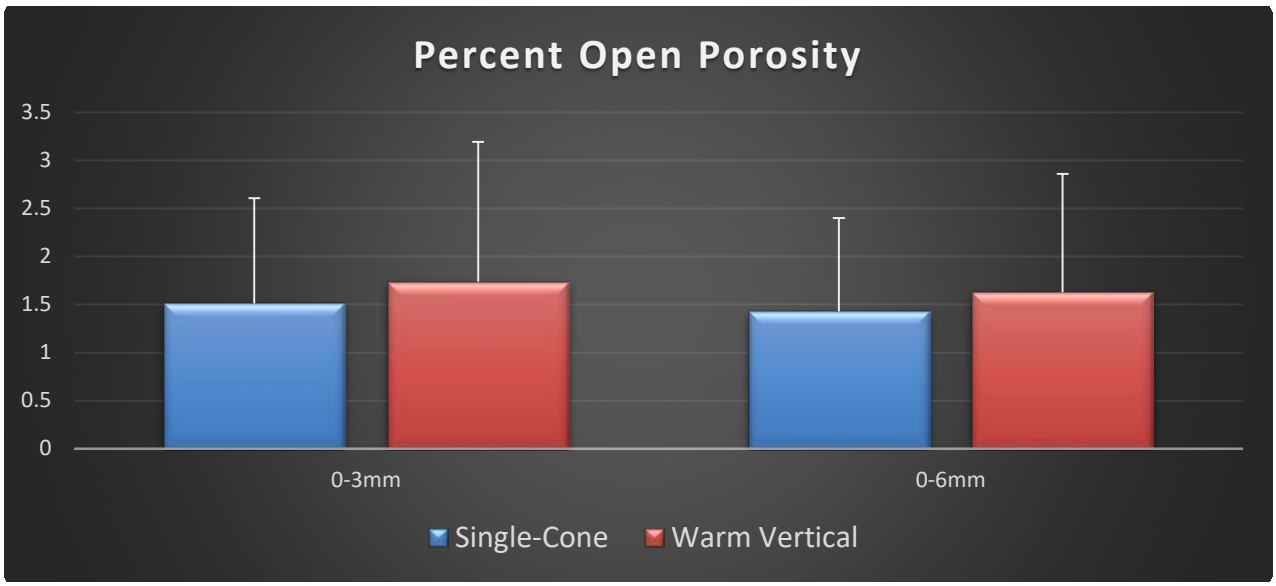

Table 2

Discussion

There are many ways to evaluate root canal sealers and root filling materials which alter the physical specimen, and are often conducted by means of dye leakage, pushout bond strength, fluid filtration, destructive visual evaluation. Evaluation of the sealer and obturation quality by non-destructive methods is ideal as it does not physically alter the specimen. Micro-CT imaging has the ability non-destructively yield extremely detailed information.

To determine our resolution quality, we tested resolutions similar to historical micro-CT obturation studies, which ranged from 8.99-17.66 µm voxel (Fig. 1)[11-13]. To most accurately threshold of grayscale values, 4.94 µm voxel size demonstrated optimal, well-defined discrimination between dentin, obturation material and porosity. Then the focus was narrowed to the apical 6 mm, which allowed for evaluation of the downpack/backfill junction, as well as the apical 3 mm Kim et al[14] describes to contain 98% of apical ramifications. With a clear visualization of sealer and GP, individual group characteristics were observed.

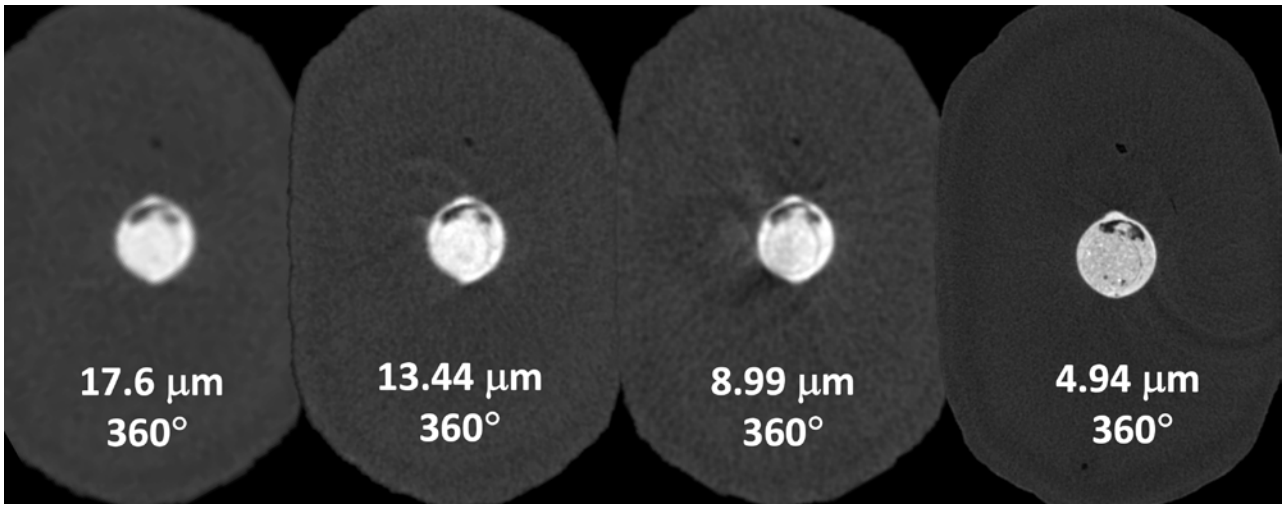

Figure 1

In our findings, both groups performed almost identically across the groups relating to open porosity, but our visual observations of the micro-CT images demonstrated very different behaviors in the SC and WV groups. The SC samples demonstrated GP cones in line with the canal surrounded by the HF sealer. The WV samples demonstrated a limited 3-dimentional GP fill (approximately 1 mm) apical to the downpack/backfill junction, then, depending on the canal morphology, varying degrees of cone deformation surrounded by the HF sealer. Low heat 150° C is advocated by the manufacturer when the WV technique is utilized. At the sealer to GP interface voids, gaps and sealer/GP was noted (Fig. 2) primarily at the inside curvature of the GP cone. These observations show the limited GP flow a WV technique has at the 150° C compared to the 3-dimensional dense GP fill Schilder describes in 1967[15].

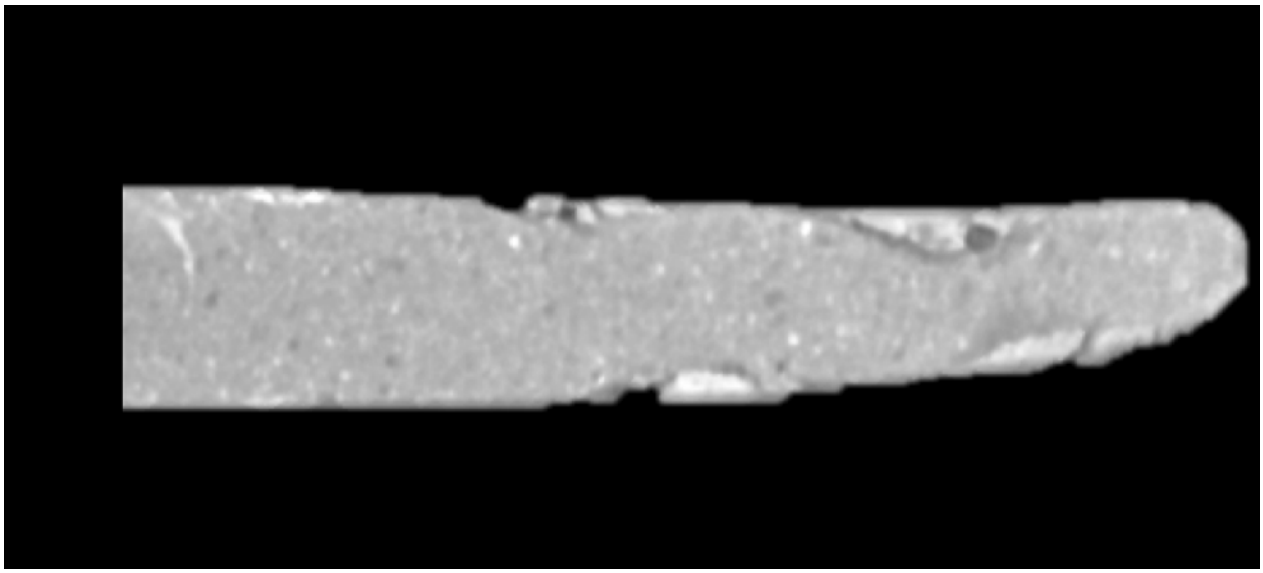

Figure 2

Additional observation to note is a mismatch of canal preparation diameter to GP cone diameter. It was noted in all SC samples the GP cone diameter was visually smaller than that of the canal preparation which ultimately gives strong indication led to the cone deformation in the WV samples. After these observations were noted, an inquiry with a manufacturer representative confirmed the GP Lot utilized in this study was fabricated with a smaller diameter. The size was corrected to provide a more precise fit with the preparation. Although the intent was to test a matched GP to file system these observations demonstrate minimal porosity is produced even with a smaller cone. The literature review by Sousa-Neto et al[16] found in the apical 1/3 up to 51% of the canal wall is untouched by instrumentation which corelates directly to the performance to the HF in the SC and WV techniques when the cone does not precisely fit the preparation.

Historically, the WV and cold lateral techniques are employed to minimize sealer interface thickness to limit shrinkage and solubility. With the net expansion of calcium silicates, the GP is used as a vehicle to express the sealer to fill canal variation and minimize porosity. The SC technique relies on a higher volume of sealer placed directly into the canal and on the cone to better fill the canal system in 3-dimentions.

The limitations of using this ex-vivo model introduces morphologic variation, which is more relevant in a clinical application. Plastic models are commonly utilized to control for this, but the

water required for setting the sealer is acquired from the dentin and cannot be replicated in a plastic model.

More studies are needed to analyze the properties changes of the HF sealer when exposed to heated instruments, how other file systems with matched GP would perform, as well as how different sealer placement methods may minimize porosity.

Conclusions

The focused of the current study was to examine the performance differences between the SC and WV techniques related to sealer porosity which leaved dentinal tubules unsealed. There is a lake of evidence how porosity relates to clinic success and such studies would be challenging and subject of a high degree of uncontrolled variables. Within the limitations of this study, micro-CT imaging and volumetric analysis shows both techniques produced statistically similar performance relating to open porosity but both but were unable to produce a void-free

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