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Evaluation of Radiopacity of Endosequence Bio-ceramic Sealer and AH Plus by Digital Radiography

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ABSTRACT

Radiopacity is a key requirement for endodontic sealers to allow radiographic distinction between obturation material and surrounding tooth structures. American National Standards Institute (ANSI) and American Dental Association (ADA) mandate a minimum of 3 millimetres of aluminium (mm Al). **Objectives:** To compare, in vitro, the radiopacity of Endo-Sequence BC Sealer versus AH Plus using digital radiography on extracted human single-rooted teeth. **Methods:** An experimental in vitro study was conducted at the Department of Operative Dentistry, Liaquat University of Medical and Health Sciences, Jamshoro. A total of 60 single-rooted teeth were selected using a non-probability convenience sampling method and allocated into two groups (n=30 each) without randomization. Care was taken to ensure that the two groups were comparable in terms of tooth type and root morphology and obturated with gutta-percha plus either Endosequence BC or AH Plus. After 7 days at 37°C/100 % humidity, radiopacity was expressed as millimetres of aluminium (mm Al). Data were compared using an independent-samples t-test ($\alpha = 0.05$). **Results:** The sample analyzed consisted of 60 samples (30 samples per group). AH Plus demonstrated significantly higher radiopacity (6.94 ± 0.46 mm Al) compared to Endosequence BC (3.83 ± 0.35 mm Al). The confidence intervals were not overlapping (AH Plus: 6.77 7.10 mm Al; Endosequence BC: 3.71 ± 3.96 mm Al). The difference was statistically very significant ($p<0.01$). **Conclusions:** AH Plus demonstrated significantly higher and more consistent radiopacity than Endosequence BC, offering superior radiographic contrast and a wider safety margin for clinical detection of obturation quality.

INTRODUCTION

The root canal system is usually filled using a combination of sealer and gutta- percha. The most common reason to use gutta-percha is its good physical and biological characteristics [1]. The disadvantage of the lack of adherence of the gutta-percha to both the cement and canal walls is also a major drawback of this material. Consequently, a sealer must be employed to ensure an intimate fit of the gutta-percha to the dentinal walls [2]. Radio-opacity is considered one of the significant properties of endodontic sealers [3]. Among other physical/chemical properties, it has been stated that the ideal root canal filling material must have a stated degree of opacity to radio-applications so that a difference may be distinguished between the material and the surrounding anatomical structure, so that the quality of root fillings can be evaluated [4-6]. The American National Standards Institute / American Dental Association (ANSI/ADA) criteria to determine the minimum requirement of the radio-opacity of the root canal filling material is that the content thereof should meet a value of radio-opacity of 3mm of

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aluminum at a thickness of 1mm [7, 8]. Radio-opacity value of Endosequence BC sealer (3.834+0.346 mm AL) and Radio-opacity of AH plus (6.936 ± 0.462 mm AL) [9, 10].

This study compares the radiopacity of the end sequence Bio Ceramic sealer and AH plus by using digital radiography. No local study has been conducted yet on this topic, and the radiopacity of endodontic sealers is a material-specific property that allows adequate visualization on radiographs, independent of operator skill or patient population. This study aimed to verify that the tested sealers meet the minimum radiopacity standards recommended by international guidelines.

METHODS

An experimental in vitro study was conducted at the Department of Operative Dentistry, Liaquat University of Medical and Health Science, Jamshoro, Hyderabad, in a time span of one year (i.e., 1-2-2020 to 31-1-2021) after the approval of the research proposal by CPSP/REU/DSG-2016-166-1860; dated 31st January 2020. A non-probability convenience sampling technique was used. The sample size was calculated by using the Open EPI sample size calculator. Sample size was calculated using Open Epi software by taking mean radiopacity values from previously published studies comparing calcium silicate-based and resin-based endodontic sealers. Based on reported mean [11] radiopacity values of approximately 3.8 ± 0.3 mm Al for bio ceramic sealers and 6.9 ± 0.4 mm Al for AH Plus, with a confidence interval of 95% and power of 90%, the required sample size was calculated to be 60 specimens (30 in each group). The study included single-rooted teeth with a mature apex as confirmed on radiographs and without any root fractures. Teeth were excluded if they had extensive caries or restorations affecting the root structure, previous endodontic treatment, periodontal disease compromising tooth stability, resorption or other internal pathology were excluded from the study. 60 extracted single-rooted teeth that satisfy the inclusion criteria were collected and were cleaned by immersing into hydrogen peroxide solution for some hours to remove any blood remnant. Access cavity was prepared, and working length was determined with a 10k file until the tip was seen to exit at the major foramen. Working length was calculated by subtracting 1mm from this measurement. Root canal was prepared with Protaper rotary files. During shaping, irrigation with 2.5% NaOCl was performed between each file. The root canal was dried with a paper point according to the filling material used. All teeth were divided into two groups. In group 1, teeth were filled with Endosequence BC sealer. In group 2, teeth were filled with AH plus sealer. In all groups, a gutta-percha cone was used. Sealers were applied with a lentulo spiral. Obturation was followed by the use of a heated Plugger to remove an excessive amount of gutta-percha to the level just short of the canal orifice, and it was compacted, and the orifice of each canal was sealed with coronal orifice. Specimens were radiographed under standardized exposure parameters with an aluminum step wedge placed alongside them for calibration. Digital images were obtained, and standardized regions of interest were selected for each specimen. Mean grey values were measured using image analysis software. A calibration curve was generated by plotting the grey values of the aluminium step wedge against its known thicknesses, and these values were used to convert specimen grey values into millimetres of aluminium (mm Al). To ensure reproducibility, measurements were performed by a calibrated examiner and repeated after a time interval, with intra-observer reliability assessed using the Intraclass Correlation Coefficient (ICC), demonstrating high agreement. Following a period of seven days, at a 37°C temperature in a humid atmosphere containing 100 percent humidity. To determine the outcomes, a digital radiograph was carried out. Radiographs were taken with the radiograph unit of 60kv and 10mA, exposure time of 0.3 seconds, and at a focus-film distance of 30cm, and then the radiographs were digitized with the use of Nikon D40 and Nikon 50-mm macro lens, and then imported into Digora 1.51 for Windows software. The values of Radiopacity are calculated based on the radiographic dentistry, which is translated to millimeters of aluminum. In this study, radiopacity was measured in root canals after obturation with the sealer and gutta-percha to simulate clinical conditions. Although gutta-percha contributes to overall radiopacity, this method reflects the material's radiographic appearance in situ, which is clinically relevant.

Data analysis was done using the Statistical Package for the Social Sciences (SPSS) version 26.0 software. Mean standard deviation was calculated for quantitative variables. Quantitative variable Radiopacity (mm Al) and Qualitative variable, like type of material or group, were measured. Normality of quantitative data was assessed using the Shapiro-Wilk test, and homogeneity of variance was evaluated using Levene's test before selecting appropriate parametric or non-parametric statistical tests. The t-test was applied by comparison between two groups, considering a p-value <0.005 significant.

RESULTS

The results show radiopacity values of millimetres of aluminium (mm Al) and show a distinct difference between the two sealers. The mean radiopacity of Endosequence BC was 3.83 mm Al ± 0.35 mm Al with the 95 percent confidence interval of 3.71 mm Al to 3.96 mm Al. Conversely, AH Plus had a significantly greater mean radiopacity of 6.94 ± 0.46 mm Al with the 95% confidence interval (6.77–7.10

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mm Al) not overlapping with that of Endosequence BC, which demonstrates that these two materials are distinctively different. This difference is also supported by the median values (6.90 mm Al of AH Plus and 3.80 mm Al of Endosequence BC) and the ranges of these values, where AH Plus is always higher than Endosequence BC. Furthermore, AH Plus has a higher degree of conformity as indicated by the comparatively low variability, which implies more consistency. The p-value (<0.001) indicates that this difference is statistically very significant. In general, AH Plus has better and more stable radiography than Endosequence BC, showing a higher chance of radiographic visibility in clinical practice (Table 1).

Table 1: Radiopacity Values Expressed as Millimetres of Aluminium (mm Al)

Sealer	n	Mean ± SD (mm Al)	Median	Min-Max	95 % CI for Mean	p-value
EndoSequence BC	30	3.83 ± 0.35	3.80	3.10 – 4.50	3.71 – 3.96	<0.001
AH Plus	30	6.94 ± 0.46	6.90	6.00 – 7.80	6.77 – 7.10	–

The left panel shows a tooth obturated with AH Plus Sealer, demonstrating dense radiopacity along the canal and extending to the apex. The right panel shows a tooth obturated with BC (bioceramic) Sealer, showing radiopaque filling with slight extrusion beyond the apex (Figure 1).

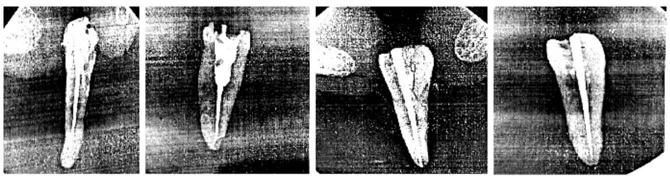

Figure 1: Radiographic Illustration of Root Canal Treatment Using Two Different Sealers

DISCUSSION

The present study demonstrated that AH Plus exhibits significantly greater radiopacity (6.94 ± 0.46 mm Al) than Endosequence BC sealer (3.83 ± 0.35 mm Al, $p<0.001$), a difference that exceeds the ANSI/ADA minimum threshold of 3 mm Al for root-canal filling materials (ANSI/ADA, 2000). This finding corroborates the earlier digital radiography work of Sen *et al.* who reported comparable values of 3.83 mm Al for EndoSequence BC [11], and supports the consensus that epoxy-resin sealers containing zirconium oxide achieve higher radiopacity than calcium-silicate-based materials [12, 13]. Clinicians will therefore perceive the distinction without sophisticated software, facilitating immediate chair-side evaluation of obturation quality. Second, AH plus surpasses the ANSI/ADA minimum by 131 %, whereas Endosequence BC exceeds it by only 28 %. This narrow margin for the bioceramic sealer raises concern that minor variations in powder-to-liquid ratio or moisture contamination during clinical use could reduce its radiopacity below the critical 3 mm Al, a risk less likely with AH Plus [14, 15]. A study by Jafari and Jafari, indicates that the leaching of radiopaque fillers can decrease contrast over time [16]. From a materials-science perspective, the superior radiopacity of AH Plus can be attributed to its inclusion of zirconium dioxide particles, which possess a high atomic number and density. Endosequence BC relies on bismuth oxide and calcium tungstate [17], yet the lower atomic number of bismuth compared with zirconium, combined with the lower filler loading required to maintain hydraulic properties, results in reduced X-ray attenuation [18]. Manufacturers of bioceramic sealers could therefore consider increasing the bismuth oxide fraction or exploring alternative high-Z additives without compromising flow or setting expansion [19]. Within the context of minimally invasive endodontics, the choice of sealer must balance biological performance with diagnostic visibility. Endosequence BC offers excellent biocompatibility and osteogenic potential, but its modest radiopacity may necessitate additional radiographic angulations to detect voids or missed canals. Conversely, AH Plus provides outstanding radiographic contrast, yet its cytotoxicity during the first 24 hours remains a concern. Clinicians should weigh these factors when selecting a sealer, particularly in complex retreatment cases where radiographic clarity is paramount [20].

A potential limitation of the study is its exclusive use of single-rooted, extracted human teeth. Multi-rooted teeth with curved canals may produce differential attenuation artefacts that alter measured radiopacity. Furthermore, storage of specimens at 37°C in 100 % humidity for only seven days may not replicate the long-term ionic exchange that occurs in vivo. Future investigations should therefore incorporate thermo-cycling and extended aging to verify stability. Clinicians should therefore reserve AH Plus for cases demanding maximal radiographic certainty, such as retreatments, complex anatomy, or when follow-up radiographs are anticipated to be challenging, whereas Endosequence BC can be chosen for straightforward cases in which its documented biocompatibility and bioactivity are paramount. Future work should evaluate long-term radiopacity stability under simulated oral conditions and extend the comparison to curved or multi-rooted teeth to confirm the generalisability of these findings.

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CONCLUSIONS

This in-vitro study confirms that AH Plus delivers significantly higher radiopacity (6.94 ± 0.46 mm Al) than Endosequence BC sealer (3.83 ± 0.35 mm Al, $p<0.001$), exceeding the ANSI/ADA minimum by 131 %. Consequently, AH Plus offers superior contrast against dentine and bone, facilitating immediate identification of voids, over-extensions, or missed canals. Endosequence BC, while surpassing the regulatory threshold, provides only a narrow safety margin; minor variations in mixing or environmental moisture could theoretically depress its radiopacity below acceptable limits.

Authors' Contribution

Conceptualization: SQ, FAK
Methodology: SQ, HO, MAP
Formal analysis: SQ
Writing and Drafting: SQ, MAP, FM, FAS
Review and Editing: SQ, FAK, HO, MAP, FM, FAS

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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