Retrievability of Calcium Silicate–based Root Canal Sealers During Retreatment: An *Ex Vivo* Study

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ABSTRACT

Introduction: The retrievability of calcium silicate–based sealers (CSSs) during nonsurgical retreatment has been equivocal. This study compared the retrievability of 3 different CSSs using 1 of 3 different solutions or no solution. **Methods:** A total of 130 extracted teeth with a straight canal were decoronated to a standardized root length. The canals were instrumented to 35/.04 and divided into 3 groups (BC: EndoSequence BC sealer; EBC: EdgeBioceramic; NEO: NeoSEALERFlo), and each group was further divided into 4 subgroups (6% sodium hypochlorite; 5% acetic acid; carbonated water; no solution). After sealer placement, each master gutta-percha cone was placed intentionally 2 mm short of the working length (WL) to ensure the apical 2 mm was filled only with sealer. After storage for 21 days at 37°C and 100% humidity, retreatment was performed until apical patency was obtained. The operator was blinded to the CSS and solution used. Data were analyzed using analysis of variance to compare apical patency rates and the mock chair-times. **Results:** Overall success rates for apical patency in BC, EBC, and NEO were 63.64%, 69.77%, and 100%, respectively. There was significantly higher apical patency rate in NEO than BC and EBC. The chair-time for NEO was significantly shorter than BC ($P < .05$) and EBC sealer ($P < .001$). There was no significant difference in the chair-time between BC and EBC sealer groups. **Conclusion:** BC, EBC, and NEO sealers in a straight canal were consistently retrievable when no solution was used. Compared with no solution, the retrievability of BC, EBC, and NEO decreased when solutions were used. *(J Endod 2022;48:781–786.)*

KEY WORDS

Apical patency; calcium silicate–based root canal sealer; retreatment; retrievability; solution

SIGNIFICANCE

During endodontic retreatment of straight canals, the retrievability of calcium silicate–based root canal sealers is more consistent when no solution is used.

When initial nonsurgical endodontic treatment fails, root canal retreatment is one of the treatment options that allows a patient to retain their natural tooth. In general, the success rate of endodontic retreatment has been reported to be comparable to those of initial root canal treatment[1–3]. However, the success rate of retreatment declines with various complications such as perforations, canal transportation, or stripping[3,4]. In addition to these complications, the obturation of the initial root canal treatment can affect the outcome of the retreatment. Root canal obturations with voids or short fills may be predictably retrieved, which results in higher success rates of the retreatment,[3] whereas obturations with acceptable length and density may be more difficult to adequately remove during the retreatment procedure.

Persistent bacterial infection in the root canal system is the most common reason for the failure of the root canal treatment[5,6], therefore it is important to eliminate all possible sources of infection during endodontic retreatment procedures. Teeth with preoperative periradicular radiolucencies, poor root canal fillings, or unsatisfactory restorations are more vulnerable to failure of the primary root canal treatment[7].

Addressing the apical foramen is the main prognostic factor in root canal treatment[8]. During retreatment procedures, clinicians must remove or penetrate the previous root canal filling materials before the working length (WL) determination. For this reason, it is necessary to establish or reestablish apical patency[9].

Calcium silicate–based sealers (CSSs) are widely used for obturation worldwide, and these sealers are commonly used with the single cone technique[10]. This obturation method has been reported to show similar success rates to traditional obturation techniques[11,12]; however, there are concerns about using

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0099-2399/$ - see front matter

https://doi.org/10.1016/j.joen.2022.02.009

CSS in this technique because the retrievability of CSSs during endodontic retreatment has not been proven[13,14]. A desirable property of a root canal sealer is retrievability. Although the gutta-percha cone, as the solitary obturation material, is easily removed[15], many clinicians are concerned about the retrievability of CSSs[10,13]. In a recent survey, 44% of the dentists considered CSSs non-retrievable[10].

Although chloroform has been used to help remove zinc oxide sealers and gutta-percha[16], the ideal solvent for CSSs has not been introduced.

The purpose of this study was to compare the retrievability of 3 different CSSs using 1 of 3 different solutions or no solution (negative control).

MATERIALS AND METHODS

Selection of Teeth

A total of 130 human single-rooted teeth were selected from a collection of deidentified teeth extracted for orthodontic or periodontal reasons. The protocol was approved by the institutional review board at The University of Texas Health Science Center at Houston. Teeth with more than 1 canal, calcified canal space, or unusual internal anatomy were excluded. An endodontic resident (operator 1) completed the initial root canal treatments, and a board-certified endodontist (operator 2) performed the retreatments in a blinded manner.

Root Canal Preparation

All teeth were disinfected and stored in a solution of 1% sodium hypochlorite (NaOCl). The teeth were decoronated to a standardized WL of 11 mm and a single canal configuration was confirmed with a radiograph. Each root canal was instrumented to a final size of 35/.04 and was irrigated using 2 mL of 6% NaOCl, (ChlorCid; UltraDent, Memphis, TN) with a 27-G side-venting needle. The canals were irrigated with 1 mL of 6% NaOCl after each introduction of a new rotary file. Two milliliters of 17% EDTA (Ultimate Dental, Memphis, TN) was used for the final irrigation rinse. The canals were dried using sterile, absorbent paper points. All roots were randomly divided into 3 groups, and each group was further divided into 4 subgroups (Fig. 1).

Root Canal Obturations

All master gutta-percha cones were placed intentionally 2 mm short of the WL, and radiographs with the master cone were taken to verify the position (Fig. 2). The canals were obturated with a single cone technique using 3 different calcium silicate–based sealers. EndoSequence BC sealer (BC sealer; Brasseler USA, Savannah, GA) was used in Group 1. EdgeBioceramic sealer (EBC sealer; EDGEENDO, Albuquerque, NM) was used in Group 2. NeoSEALERFlo (NEO sealer; Avalon Biomed, Houston, TX) was used in Group 3. After all canals were obturated, radiographs were taken to evaluate the obturation (Fig. 2). All teeth were stored for 21 days at 37°C and 100% humidity.

Endodontic Retreatment

Each of the 3 groups was subdivided into 4 subgroups (Fig. 1) corresponding to the solutions used during retreatment procedures. Three solutions were 6% sodium hypochlorite, 5% acetic acid (Lab Chem, Zelienople, PA), and carbonated water (HEB). In the fourth subgroup, no solution was used.

Retreatment Protocol

Operator 2 was blinded to the sealers and solutions, except for the subgroup using no

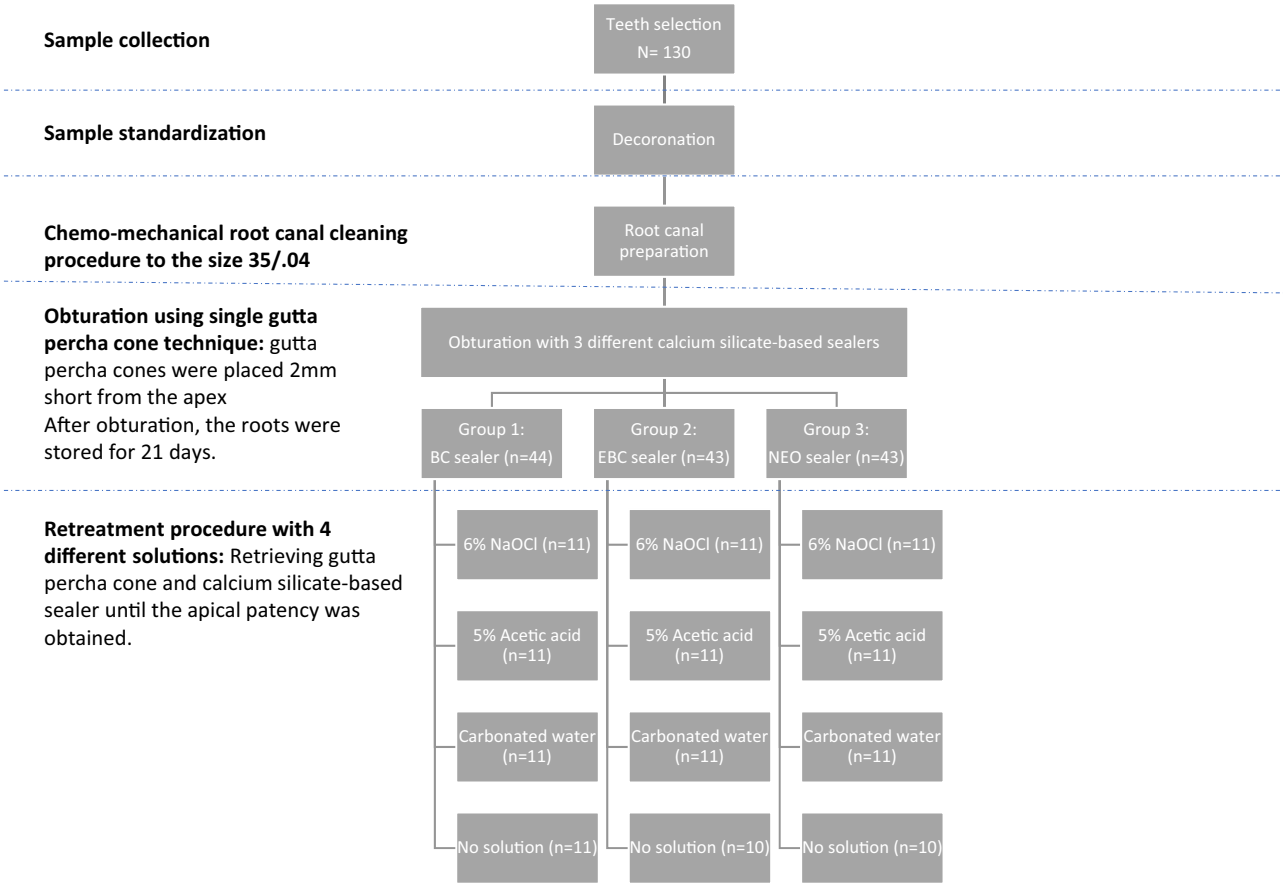

FIGURE 1 – The flow diagram of the study with 3 different groups and 4 different subgroups.

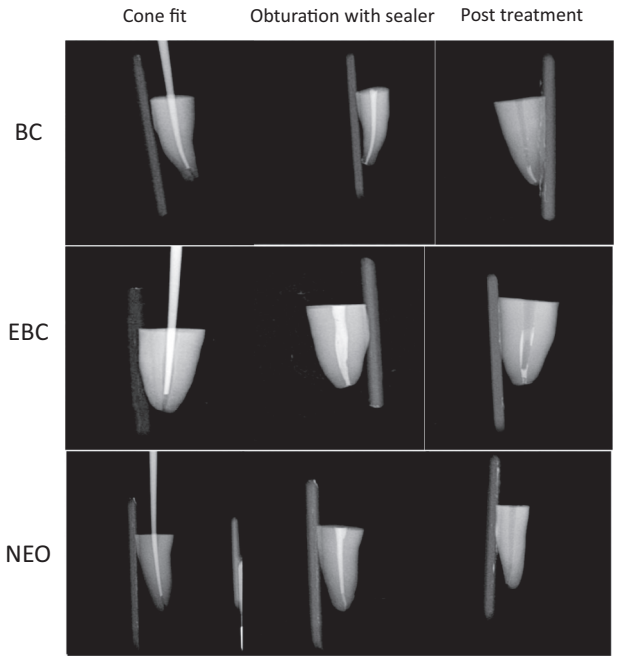

FIGURE 2 – The representative radiographs of the teeth samples. Note: Single cone gutta-percha cones were intentionally fit short 2 mm from the apices. BC, EndoSequence BC sealer; EBC, EdgeBioceramic; NEO, NeoSEALERFlo.

solution. Each tooth was labeled with a number, and the syringes of the solutions were completely masked by green paper. In addition, an N95 respirator was used to ensure that the operator did not perceive the solution's odor.

In each retreatment, the following protocols were used: the cervical one-third of gutta-percha was removed using a size 35/.04 heat-activated plugger (Alpha II; B&L Biotech, Fairfax, VA) for 5 seconds at 200°C. All engine-driven rotary files were operated using the X-Smart IQ handpiece (Dentsply; Tulsa Dental Specialties, Tulsa, OK) at a speed of 500 rpm and a torque of 3.0 Ncm. EdgeTaper Retreat files, D1: 30.09, D2: 25.08, and D3: 20.07, and Dentsply Maillefer Ready Steel 21 mm C + File #10.02 (Dentsply; Tulsa Dental Specialties) were used in order. After the instrumentation of D1 and D2, each canal was irrigated with 2 mL of the test solution. D3 was used combined with size 10 C+ hand files with 3 mL of the test solution until apical patency was obtained. Ten minutes was preset as a time limit to reestablish patency. Two final radiographs were taken by operator 1.

Statistical Analysis

Analysis of variance (ANOVA) tests of general linear model were produced to compare the rates of gaining apical patency and mock chair-times in 3 different sealer groups: BC sealer, EBC sealer, and NEO sealer. R statistical software (R Foundation for Statistical Computing, Vienna, Austria; https://www.Rproject.org/) was used for statistical analysis.

RESULTS

Apical patency was gained in 100% of the NEO sealer group, including all solutions and the no-solution group (Table 1). The overall success rate of gaining apical patency in the BC sealer group was 63.64%. The overall success rate of apical patency in the EBC sealer group was 69.77%. ANOVA showed there was significantly higher success rate of gaining apical patency in the NEO sealer group than the BC and EBC sealer groups ($P = 3.45^{-7}$). Apical patency was obtained significantly more when no solution was used compared with when 6% NaOCl, 5% acetic acid, or carbonated water were used in the BC and EBC groups ($P < .01$). Without solution, apical patency was obtained in 10 (91%) of 11 teeth in the BC sealer group and 10 (100%) of 10 teeth in the EBC sealer group (Table 1). The chair-time for obtaining apical patency in the NEO sealer group was significantly shorter than BC ($P < .05$) and EBC sealer ($P < .001$) groups (Fig. 3); however, there was no significant difference in the chair-time between BC and EBC sealer groups (Fig. 3).

DISCUSSION

In this study, the authors used 3 different solutions for retreatment: carbonated water,

TABLE 1 - The Rates of Gaining Apical Patency and Their Chair-times in 3 Different Sealer Groups and 4 Different Subgroups

	Group 1: BC sealer			Group 2: EBC sealer			Group 3: NEO sealer		
	Success rate of apical patency (%)	Chair-time (s)		Success rate of apical patency (%)	Chair-time (s)		Success rate of apical patency (%)	Chair-time (s)	
Solutions		Mean	SD		Mean	SD		Mean	SD
6% NaOCl	45.45	254.60	76.49	45.45	339.40	149.90	100.00	87.82	22.77
5% Acetic acid	63.64	301.00	180.94	54.55	175.00	82.83	100.00	66.82	16.25
Carbonated water	54.55	293.00	131.19	81.82	273.22	167.63	100.00	70.45	17.06
No solutions	91.00	287.70	170.69	100.00	229.90	136.33	100.00	169.40	103.75
Total	63.64			69.77			100.00*		

BC, EndoSequence BC sealer; EBC, EdgeBioceramic; NEO, NeoSEALERFlo.
Note: In Group 1, 1 file (D3) separated during removal of BC sealer when no solution was used. In the sample with separated file, apical patency was not obtained.
*There was significantly higher success rate of gaining apical patency in the NEO sealer group than in the BC and EBC sealer groups ($P < .001$).

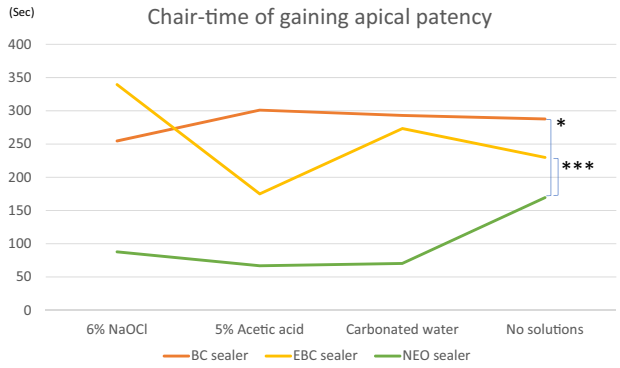

FIGURE 3 – Chair-time of gaining apical patency in BC, EBC, and NEO sealer groups. Simultaneous tests for general linear hypotheses showed no significant different chair-time between BC and EBC sealers ($P > .05$). However, NEO sealer was retrieved and the apical patency was gained with significantly shorter chair-time compared with BC and EBC sealers (*$P < .05$ and ***$P < .001$, respectively). BC, EndoSequence BC sealer; EBC, EdgeBioceramic; NEO, NeoSEALERFlo.

acetic acid, and sodium hypochlorite. CSSs can be damaged by carbonation reaction. Carbonated water contains dissolved carbon dioxide gas, which reacts with calcium hydroxide. CSSs may structurally be weakened by carbonated water, forming calcium carbonate and releasing water.

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$

Acetic acid can be used as a disinfectant and chelating agent in the root canal[17]. Theoretically, by facilitating leach-out of calcium ions, acetic acid can increase the solubility of CSSs during retreatment. Sodium hypochlorite (NaOCl) is routinely used to disinfect the root canal[18]; hence, it is useful to know the efficacy of NaOCl in retrieving CSSs during retreatment.

The retrievability of the calcium silicate–based sealers was demonstrated in this study. Apical patency was obtained in all teeth using hand and engine-driven files within 10 minutes when no solution was used, except for 1 sample (Table 1) in which a D3 file separated in the BC sealer group when no solution was used. Six percent NaOCl, 5% acetic acid, and carbonated water decreased the success rates of obtaining apical patency (Table 1). When the liquids NaOCl, acetic acid, or carbonated water are absorbed into the pores of CSSs, they may possibly dampen the energy of the retrieving motion[19]. Future study should investigate the effect of pore-liquid on the strength of CSSs.

A previous *ex vivo* study reported that canals obturated short with a single gutta-percha cone and calcium silicate–based sealer were not entirely penetrable to WL[13]; however, the mesiobuccal canals of the mandibular molars were used in their retreatment study[13]. The short root canal filling in the curved root is a predisposing factor for the ledge formation during an attempt to establish patency[20]. Also, chloroform was used to dissolve the gutta-percha cone and BC sealer (Brasseler USA) or AH plus sealer (Dentsply)[13].

The use of chloroform in endodontic treatment can be controversial. Although it is effective in dissolving obturation materials such as gutta-percha, chloroform can be toxic if it is ingested or inhaled in sufficient quantities[21–24]. In an animal study, cleft palate was reported among the offspring when chloroform was inhaled by pregnant mice[25]. Despite the advantages of chloroform, as health providers, dentists need to develop protocols for endodontic retreatment based on human safety. The retreatment technique reported by Hess et al[13] that used chloroform to retreat teeth obturated with bioceramic sealers was deemed ineffective. The authors recommended further studies using new solvents or techniques[13]. This *ex vivo* study highlights the efficacy of retreating teeth obturated with CSS without the need for solvents.

In this study, only single straight root canals were used, and the teeth were decoronated to standardize the length of the samples. Also, the retreatments were performed 3 weeks after the obturation. These aspects of this *ex vivo* model might increase the retrievability or penetrability of the CSSs. On the other hand, the design of this study ensured that only CSSs sealed the last 2 mm of the root canals without gutta-percha cones. This enabled the assessment of the retrievability of CSSs in cases in which the gutta-percha cone stops short of the canal terminus. However, this model may not represent the typical clinical case. In this study, mock chair-time was restricted to 10 minutes. In a clinical situation, the available chair-time can be much greater as needed.

The mock chair-time for the retreatment of teeth obturated using NEO sealer was significantly shorter than those obturated using BC and EBC sealers. The retrievability of NEO sealer for apical patency was shown by 100%, regardless of the tested solutions or no solution. This is a positive factor when retreatment is necessary; however, it is unknown how the retrievability of NEO sealer could factor in the long-term outcome of the primary root canal treatment. Therefore, future studies should investigate the long-term outcome of root canal therapy using NEO sealer.

A pilot study showed that the compressive strengths of BC sealer, EBC sealer, and NEO sealer were similar, with a mean value of 25 ± 0.5 Megapascal. However, in this study, the retrievability of NEO sealer was significantly higher than that of BC sealer or EBC sealer, which indicates that the compressive strength does not reflect the resistance of the sealers against this retrievability test. Future studies are necessary to measure shear strength and/or tensile strength of the sealers.

CONCLUSION

In this study, BC, EBC, and NEO sealers in a straight canal were consistently retrievable, and apical patency was able to be obtained when no solution was used. Compared with no solution, the retrievability of BC, EBC, and NEO sealers was decreased when 6% NaOCl, 5% acetic acid, or carbonated water was used. The retrievability of NEO sealer was significantly higher, with a shorter chair-time required compared with that of BC or EBC sealer.

ACKNOWLEDGMENTS

The authors acknowledge the support of the Foundation for Endodontics and the Endodontics Department at the University of Texas School of Dentistry at Houston. American Association of Endodontists Foundation Resident Research Grant to Dr. Carlos A. Carrillo. The authors also acknowledge Dr. Joe C. Ontiveros for assistance with the Instron machine at Houston Center for Biomaterials and Biomimetics, and Dr. Hyeon-Cheol Henrry Kim for his feedback on the manuscript. The authors also thank Brasseler, Edge Endo, and Avalon Biomed, which provided material support for this project. The authors deny any conflicts of interest related to this study.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT:

Carlos A. Carrillo: Investigation, Data curation, Writing—original draft preparation. **Timothy Kirkpatrick**: Supervision, Investigation, Writing—review & editing. **Kim Freeman**: Investigation, Writing—review & editing. **Scott R. Makins**: Investigation, Writing—review & editing. **Mustafa Aldabbagh**: Investigation, Writing—review. **Ji Wook Jeong**: Conceptualization, Methodology, Investigation, Data curation, Visualization, Writing—review & editing

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