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Is the EndoSequence BC Sealer more beneficial in the endodontic obturation of permanent teeth than the AH Plus which is presented as being the gold standard treatment?

Revisão sistemática integrativa

Alexine DI LORENZO

Dissertação conducente ao **Grau de Mestre** em **Medicina Dentária (Ciclo Integrado)**

Gandra, **maio de 2023**

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Trabalho realizado sob a Orientação de Dr.**Luís Caetano**

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Eu, Alexine DI LORENZO, declaro ter atuado com absoluta integridade na elaboração deste trabalho, confirmo que em todo o trabalho conducente à sua elaboração não recorri a qualquer forma de falsificação de resultados ou à prática de plágio (ato pelo qual um indivíduo, mesmo por omissão, assume a autoria do trabalho intelectual pertencente a outrem, na sua totalidade ou em partes dele). Mais declaro que todas as frases que retirei de trabalhos anteriores pertencentes a outros autores foram referenciadas ou redigidas com novas palavras, tendo neste caso colocado a citação da fonte bibliográfica.

AGRADECIMENTOS :

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A vida é feita de muitos pequenos renascimentos que foram possíveis graças às pessoas que amo.
Aprendi e saio diferente, mas pronta!

RESUMO:

Introdução: O tratamento endodôntico não cirúrgico tem por objetivo tratar a periodontite apical. A obturação do sistema de canais é fundamental para a longevidade do sucesso do tratamento.

Objetivo: Descobrir se o EndoSequence BC sealer é mais benéfico do que o tratamento "gold standard" AH Plus durante a fase de obturação, determinar qual desses dois cimentos é mais confortável para o dentista e se os resultados são satisfatórios.

Material e método: Pesquisa bibliográfica eletrônica de artigos científicos em dois bases de dados eletrônicas: *PubMed* para uma revisão sistemática integrativa.

Resultados: 407 artigos ao todo, dos quais 23 foram obtidos após a aplicação dos critérios de inclusão e exclusão, com a remoção de artigos duplicados e dos considerados irrelevantes, a leitura dos títulos e textos integrais.

Discussão: O EndoSequence BC Sealer apresenta melhor ação antibacteriana e biocompatibilidade em comparação ao AH Plus devido à sua composição química e capacidade de gerar uma reação de hidratação para criar hidroxiapatita na regeneração das células dentinárias hospedeiras. O retratamento endodôntico é mais fácil com ambos os cimentos, utilizando clorofórmio, e suas propriedades físicas são semelhantes.

Conclusão: O EndoSequence BC sealer não é mais vantajoso do que o AH Plus em todos os aspectos e características. O sucesso, o conforto para o paciente são semelhantes e os novos formatos disponíveis desses cimentos adaptam-se às preferências do médico dentista.

Palavras-chaves: «epoxy resins», «AH Plus», «biosilicate cement», «EndoSequence BC» «bioceramics sealers».

ABSTRACT:

Introduction: Non-surgical endodontic treatment consists of a set of procedures that aim to prevent or treat apical periodontitis.

Objetive: Find out whether the EndoSequence BC sealer is more beneficial than the gold standard AH Plus during the obturation phase, to determine which of these two endodontic cements is more comfortable for the dentist, and whether the results are satisfactory.

Material and method: An electronic literature search of scientific articles was conducted in two electronic research databases: *PubMed* for an integrative systematic review.

Results: A total of 407 articles were found. 23 articles were obtained after respecting the inclusion and exclusion criteria, with the removal of duplicate articles and because of reading the titles and the full texts considered irrelevant.

Discussion: The EndoSequence BC Sealer shows better antibacterial action and biocompatibility compared to the AH Plus due to its chemical composition and ability to generate a hydration reaction to create hydroxyapatite in regenerating host dentin cells. Endodontic retreatment is easier with both cements using chloroform, and their physical properties are similar.

Conclusion: The EndoSequence BC Sealer is clearly not more advantageous than AH Plus in all aspects and features. Success and comfort for the patient are similar and the newly available shapes of these sealers are adapted to the dentist's preferences.

Keys words: «epoxy resins», «AH Plus», «biosilicate cement», «EndoSequence BC» «bioceramics sealers».

TABLE OF CONTENTS

1) INTRODUCTION:.....1
2) OBJECTIVE:.....3
3) MATERIAL AND METHODS:.....4
3.1 Eligibility criteria for the PICo method (qualitative question):.....4
3.2 Inclusion criteria:.....5
3.3 Exclusion criteria:.....5
4) RESULTS:.....7
5) DISCUSSION:..... Erreur ! Signet non défini.
5.1. Chemical properties of EndoSequence BC sealer (Brasseler USA, Savannah, GA) and AH Plus (Dentsply De Trey Gmbh, Konstanz, Germany).....21
Composition.....21
Ca^{2+}Release.....22
pH.....23
Radiopacity.....24
5.2 Biological properties of EndoSequence BC sealer (Brasseler USA, Savannah, GA) and AH Plus (Dentsply De Trey Gmbh, Konstanz, Germany).....25
Antimicrobial activity.....25
Cytotoxicity, cytocompatibility and Genotoxicity.....26
The pain.....27
5.3. Physical and mechanical properties ESBCS (Brasseler USA, Savannah, GA) and AHP (Dentsply De Trey Gmbh, Konstanz, Germany).....28
Solubility, flow, viscosity, and dimensional stability.....28
Setting time and working time.....28
Sealing ability, tubule penetration and thickness.....29
Push-Out Bond Strength (with or without gutta-percha) and Characterization.....30
Leakage.....30
Fracture resistance.....31
Root canal retreatment.....31
5.4. Estimation of the ease of use of the sealers for the dentist. Non-surgical endodontic root canal treatment outcome with EndoSequence BC sealer and AH Plus.....32
6) CONCLUSION.....34
7) BIBLIOGRAPHIC REFERENCES.....35

TABLE OF FIGURES:

Figure 1: PRISMA 2020 flow diagram for new systematic reviews which include searches of databases and registers only. 6

TABLES OF CHARTS:

Table 1:Questions of interest based on the study population (P), the interest of the technique studied (I) and the context (Co) PICo method. 4

Table 2: Table of results grouping together all articles used in this study. 20

LIST OF ABBREVIATIONS:

ISR: Integrative systematic review

ESBCS: EndoSequence BC sealer

AHP: AH Plus

NSERCT: Non-surgical endodontic root canal treatment

BCBS: Bioceramic-based sealer

ERBS: Epoxy-resin-based sealer

Micro-CT: Micro-computed tomography

SEM: Scanning electron microscopy

WVT: Warm vertical compaction technique

LCT: Lateral compactation technique

ADT: Agar diffusion test

DCT: Direct contact test

EDS: Energy Dispersive Spectroscopy

SBT: Sealer-based filling technique

CWCT: Continuous-wave condensation technique

SCT: Single cone technique

NSR: Non-surgical retreatment

CBCT: Cone Beam Computed Tomography

1) INTRODUCTION:

The goal of non-surgical root canal treatment (NSRCT) is to treat the inside of teeth when they present diseases like inflammatory and infectious reactions. The treatment aims to preserve teeth by performing conservative procedures to treat pulp necrosis and irreversible pulpitis (1–3).

This integrative systematic review (ISR) focuses on the obturation phase of this endodontic treatment, which involves sealing the root canal carefully and hygienically to avoid any proliferation of pathogenic agents that could lead to treatment failures. The use of incorrect materials can cause microleakage, allowing access of bacteria, fluids, ions, or molecules between the restorative material and the tooth (4) Endodontic failures are reported in 14-22% of cases (2,5). Therefore, materials used for root canal filling are crucial for long-term treatment success (4).

The obturation should allow a hermetic, homogeneous, and dense sealing from the apex to the coronal end of the root canal, thanks to sealers that sanitize periapical tissues and resolve periapical lesions without showing cytotoxicity or causing any inflammatory reaction in the host (4) .

To optimize success, sealers must be stable over time, have an excellent seal and set, have an optimal setting time, good anatomical adaptation, be dimensionally stable, present good radiopacity, biocompatibility, low cytotoxicity, and genotoxicity, be insoluble in tissue fluids, stable in color, have antibacterial and bacteriostatic effects, and have an ideal bioactive action with the stimulation of hydroxyapatite creation in contact with body fluids.

In addition, sealers should cause minimal post-obturation pain, adhere well to the walls of the canals with dentin, and be reworkable in case of failure to remove the material for retreatment, ensuring long-term durability of the treatment (1,4,6).

Various endodontic sealers are available, such as zinc oxide-eugenol sealers, salicylate sealers, zinc oxide-fatty acid sealers, glass ionomer sealers, silicone sealers, epoxy resin-based sealers, tricalcium silicate sealers, and methacrylate resin sealers (4,7).

The epoxy-resin-based AH Plus sealer is often considered the "gold standard" treatment and is very popular (8,9). Most recently, Endosequence BC sealer, an expensive premixed bioceramic endodontic sealer, has generated enthusiasm and is popular and promising because of its physical and biological properties (3,7,10,11).

Is the most recent sealer, the EndoSequence BC sealer, really more advantageous than the epoxy-resin-based sealer AH Plus?

In the first part of this study the chemical properties of these sealers will be discussed, in the second part of this work, their biological properties will be studied. In the third part, the physical properties will be analyzed and in the last part, an estimation of the ease of use of the sealers for the dentist and an estimation of the outcome of the non-surgical endodontic root canal treatment will be realized.

2) OBJECTIVE:

The primary objective of this integrative systematic review is to determine whether EndoSequence BC sealer is more advantageous than AH Plus for endodontic obturation during the non-surgical endodontic root canal treatment.

The secondary objective of this study is to evaluate the comfort level for the dentist while using each sealer and to assess whether the outcomes achieved with these sealers bring satisfaction.

3) MATERIAL AND METHODS:

An electronic bibliographic search was conducted to find scientific articles that investigate which one of EndoSequence BC sealer or AH Plus, is the most effective and convenient for the patient and the dentist.

Two electronic research databases were selected to achieve the objective of this study: *PubMed* with the keywords «epoxy resins», «AH Plus», «biosilicate cement», «EndoSequence BC» «bioceramics sealers».

The search terms used in *PubMed* were: ((((epoxy resins[MeSH Terms]) OR (AH Plus)) AND (biosilicate cement)) OR (EndoSequence BC)) OR (bioceramics sealers)
The selection of articles was carried out using the PICo method.

3.1 Eligibility criteria for the PICo method (qualitative question):

Population (P)	Patients who suffer from pulp necrosis or irreversible pulpitis and who need a non-surgical endodontic treatment.
Interest (I)	Study two types of sealers EndoSequence BC sealer and AH Plus, during the obturation phase in the non-surgical endodontic root canal treatment and understand which one can be the most appropriate for the patient and the dentist. Learn if the most recent sealer EndoSequence BC sealer is the most suitable in these cases.
Context (Co)	Use the EndoSequence BC sealer and AH Plus in the non-surgical endodontic root canal treatment. Observe the chemical, biological, physical properties of these sealers and the adaptation of the patient and the dentist.

Table 1:Questions of interest based on the study population (P), the interest of the technique studied (I) and the context (Co) PICo method.

3.2 Inclusion criteria:

- Only articles published within the last 10 years and conducted on human patients rather than animals were considered. These criteria are the ones respected with the filter of the Database, the others were done with reading of the articles.

- These articles were required to have a relevant title, abstract, and content.

- Additionally, it was essential that the articles were written exclusively in English.

- The studies encompassed various types, such as clinical trials, retrospective studies, experimental studies, randomized studies, outcome studies, in vitro studies, in vivo studies, SEM and micro-CT studies, retrospective analysis studies, confocal laser scanning microscopy studies, non-randomized clinical trials, prospective clinical trials, and comparative studies.

3.3 Exclusion criteria:

- Articles older than 10 years (prior to 2012) were excluded. This criteria was applied using the database filter, while the remaining criteria were determined through article reading.

- Articles with irrelevant titles or abstracts were rejected.

- Meta-analysis articles, integrative reviews, and articles in languages other than English were also excluded.

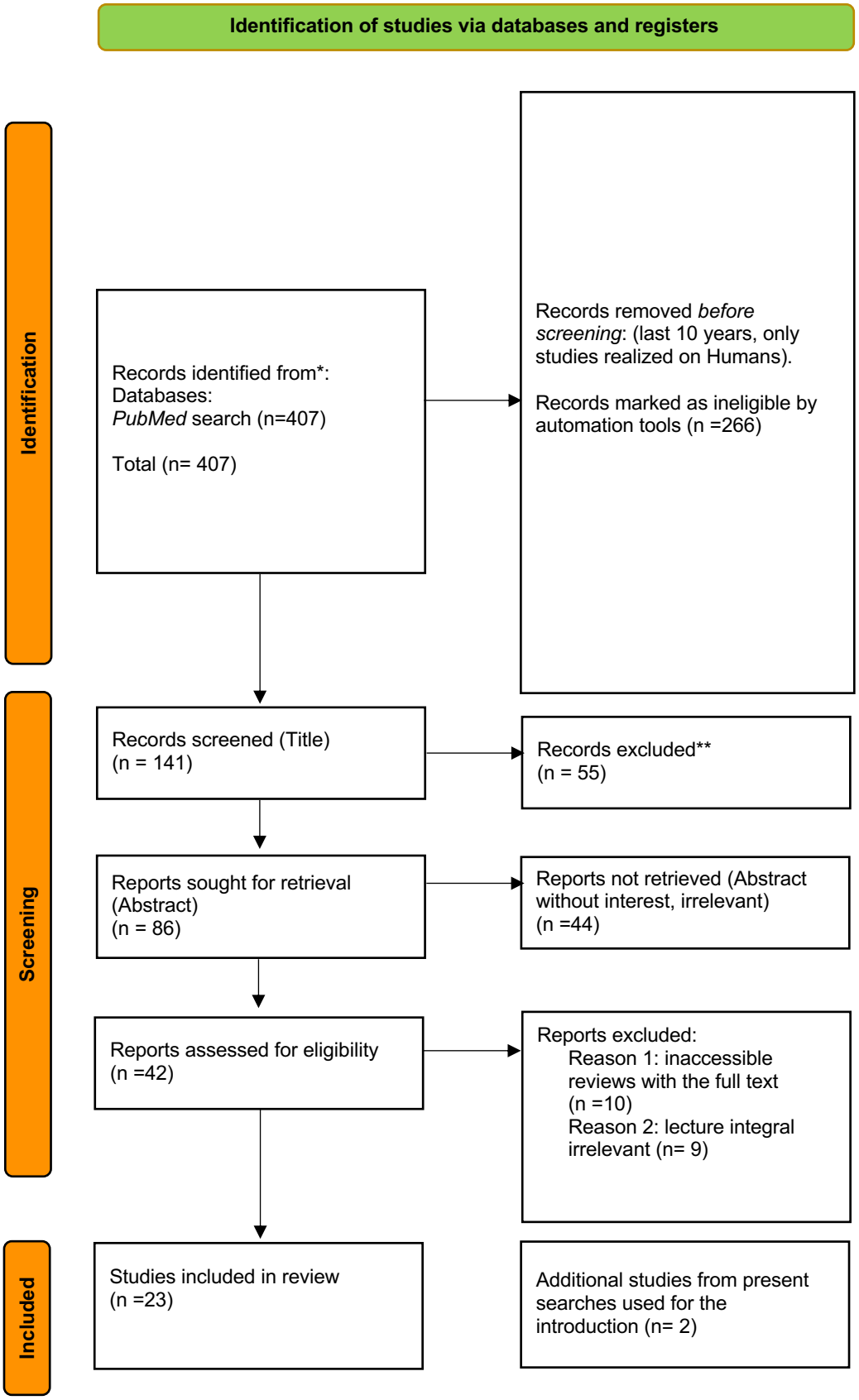

Figure 1: PRISMA 2020 flow diagram for new systematic reviews which include searches of databases and registers only.

4) RESULTS:

A complete and deep reading of the final 25 (only two of them were only used in the introduction) relevant articles that we found on the *PubMed*.

To accomplish this work, these articles were recorded in a table of results.

ARTICLES	OBJECTIVES	METHODS	RESULTS	CONCLUSIONS
«Evaluation of Radiopacity, pH, Release of Calcium Ions, and Flow of a Bioceramic Root Canal Sealer». *Candeiro e Al* *2012*	Judge physicochemical properties of Endosequence BC sealer (ESBCS). Analyze radiopacity, pH, release of calcium ions (Ca^{2+}), and flow. Study these results with AH Plus (AHP).	-Radiopacity and flow evaluated following ISO 6876/2001 standards. Metallic rings were filled with sealers for radiopacity analysis. -Flow test conducted using 0.05 mL of sealer on a glass plate with a 120g weight. pH and Ca2+ release measured at various time intervals. -Data were analyzed using ANOVA and Tukey test (P < 0,05) in SPSS software 15,0.	-The bioceramic-based sealers (BCBS) indicate a value of radiopacity (3,84 mm Al) significantly lower than that of the AH Plus (AHP) (6.90 mm Al). But this value is above the recommendation of ISO 6786/2001. -EndoSequence BC sealer (ESBCS) has an alkaline pH in all experimental times. AH Plus (AHP) has a moderately neutral pH. -EndoSequence BC sealer (ESBCS): greater release of the ion Ca^{2+} than those of AH Plus (AHP) (P < 0,05) during the experimental periods. -EndoSequences BC sealer (ESBCS) and the AH Plus (AHP) presented a flow value respectively of 26,96 mm and then 21,17 mm (P<0,05). The AH Plus (AHP) exhibited a flow value considerably lower than that of the EndoSequence BC sealer (ESBCS).	EndoSequence BC sealer (ESBCS) revealed a radiopacity value and a flow value in agreement with the ISO 6876/ 2001 recommendations. The other physicochemical properties analyzed demonstrated favorable values for sealer. (J Endod 2012;38:842–845).
«In Vitro Fracture Resistance of Roots Obturated with Epoxy Resin–based, Mineral Trioxide Aggregate–based, and Bioceramic Root Canal Sealers». *Topçuoglu e Al* *2013*	Assess the fracture resistance of teeth that has been filled with 3 different endodontic sealers.	-75 single-rooted premolars extracted from patients aged between 40 and 45 years for periodontal reasons. -Teeth decoronated to a 13 mm section and divided into 5 groups. Group 1 served as the negative control, while Group 2 was the positive control. Groups 3, 4, and 5 were prepared using different sealers with gutta-percha. After 14 days of incubation under 100% humidity, the	-Split vertical fracture in the direction buccolingual: the most detected type of fracture. -The fracture values of the group 3, group 5 were higher than those of the group 4 (P<0,05). There was no disparity between groups 3 and 5 (P >0,05).	Within the restriction of this study, there is no considerable difference between AHP and ESBCS. ESBCS and AH Plus Jet sealer were able to increase the force to fracture in single-rooted

		specimens underwent fracture testing using a universal testing machine. The force required for fracture was recorded. -Statistical analysis was performed using one-way ANOVA with Tukey's post hoc test (P<0,05) for multiple comparisons.		premolar tooth endodontically treated.
«Physical Properties of 5 Root Canal Sealers». *Zhou e Al* *2013*	Assess the change of pH, viscosity, and others physical properties of two novel root canal sealers (MTA Fillapex and ESBCS) in contrast with 2 ERBS (AHP and ThermaSeal), (Pulp Canal Sealer), and with a silicone-based sealer (Gutta- Flow).	-Study: followed ISO 6876/2001 specifications. -pH change of freshly mixed and set sealers evaluated over 1 and 35 days. Viscosity was tested at different injection rates. Data were analyzed using one-way ANOVA (P<0,05).	-Film thickness, dimensional change, flow and solubility of all sealers of this study agreed with the ISO 6876/2001 recommendations. -MTA Fillapex sealer: higher flow than the ESBCS(P<0,05). MTA Fillapex and ESBCS showed the highest film thicknesses during the tested samples. -ESBCS: highest value of solubility, which was in accordance with 3% mass fraction advised by the ISO 6876/2001 recommendations, and it showed an acceptable dimensional change. -Fresh samples of ESBCS, MTA Fillapex, AHP and Thermaseal showed an alkaline pH but only ESBCS and MTA Fillapex showed an alkaline pH after setting. -Fresh samples of the AHP and ThermaSeal has a pH alkaline at first but then decreased after 24 hours of use.	Sealers are pseudoplastic according to their definite viscosities. MTA Fillapex and ESBCS each possessed comparable flow and dimensional stability but a higher film thickness and solubility than AHP, ThermaSeal, PCS and Guttaflow. sealers (J Endod 2013;39:1281–1286).

			-Viscosity the sealers of this present study increased with the decreased injection rates.	
«Interfacial adaptation and thickness of bioceramic-based root canal sealers». *Al-Hadda e Al* *2015*	Evaluate, compare thickness of the sealers and the interfacial adaptation of BCBS, MTA Fillapex, ESBCS to the root canal dentin against AHP.	-60 single-rooted premolars divided into four groups and obturated using the cold lateral compaction technique. -Presence of sealers and gap-containing regions evaluated at different root canal levels. ANOVA analysis (P=0,05) performed to compare the different sealers and root canal levels.	-Sealer thickness: higher at the apical and at the middle levels of the tooth than at the coronal level. -ESBCS: highest thickness compared to MTA Fillapex and AHP. The coronal level had considerably less interfacial gaps compared to the apical level and to the middle level.	ESBCS had considerably higher thickness than AHP and MTA Fillapex. BCBS showed more gaps compared to ERBS AHP, with no substantial differences between them.
«Comparisons of the Retreatment Efficacy of Calcium Silicate and Epoxy Resin–based Sealers and Residual Sealer in Dentinal Tubules ». *Kim e Al* *2015*	Appraise the efficacity of the root canal retreatment and the amount of residual sealer in a single root canal tooth filled with ESBCS or AHP.	-Study: compare the use of AHP and ESBCS sealers in 28 extracted teeth. -Retreatment time, canal cleanliness, and sealer penetration evaluated. -Statistical tests used for analysis.	-Any significant divergence between the 2 groups in the amount of number of debris, dentin penetration, or retreatment time observed. -With the respect to penetration depth, AHP group revealed a higher percentage than BCBS group, with a significant difference only in the portion at 6 mm from the apex (P<0,05). -SEM images: presence of debris remaining on canal walls in both groups, whereas canal patency in retreatment was achieved in a lot of specimens.	No considerable difference in retrievability between AHP and ESBCS. AHP showed a seriously higher percentage in penetration depth of the coronal portion. ESBCS and AHP showed similar characteristics in the retreatment procedures.

« In Vitro Cytotoxicity of Calcium Silicate–containing Endodontic Sealers ». *Zhou e Al* *2015*	Explore the cytotoxicity of ESBCS MTA Fillapex and a control ERBS AHP on human gingival fibroblasts.	ESBCS, MTA Fillapex, and ERBS AHP evaluated. -Human gingival fibroblasts incubated with extracts from fresh and set materials, as well as cultured on the surface of the set materials. -Cytotoxicity evaluated using flow cytometry, and fibroblast adhesion was assessed with SEM. -Cell cytotoxicity data analyzed using a one-way ANOVA test at a significance level of (P<0,05).	-Cells incubated with extracts from ESBCS: higher viability at all extract concentrations than the cells incubated with extracts from freshly mixed AHP and fresh and set MTA Fillapex, notably for the high extract concentrations (1:2 and 1:8 dilutions). -Extracts from set MTA Fillapex of 14 days and older were more cytotoxic than extracts from freshly mixed and 1-week-old sealer. -ESBCS: any cytotoxicity at any stage of the setting. -AHP: cytotoxic in a concentration-dependent manner (cytotoxic 14 days.). AHP no longer showed cytotoxicity and the fibroblast cells proliferated in the AHP similarly than for the ESBCS. -MTA Fillapex was cytotoxic throughout the 1 month test periods and SEM images of cell culture experiments showed damaged fibroblasts on the surface of this sealer. But there was no longer cytotoxic with extract concentrations of 1:32 and lower.	ESBCS and MTA Fillapex exposed a different cytotoxicity to human gingival fibroblasts. ESBCS revealed a better cytotoxicity to the human gingival fibroblasts than MTA Fillapex. AHP was only cytotoxic at the time of the preparation of the sealer, when it's freshly mixed it was cytotoxic but then it allowed a growth and positive evolution for the gingival fibroblasts on the surface of the set material used. (J Endod 2015;41:56–61).
«Cytocompatibility of calcium silicate-based sealers in a three-dimensional cell culture model». *Leal da Silva e Al* *2016*	Estimate the cytotoxic effects and the cytokine production of EndoSeal, ESBCS, and MTA Fillapex with an in vitro root canal filling model and 3D cell culture.	-30 human maxillary incisors with straight roots and an initial apical size of 10K file prepared using a single-file reciprocating technique. -The canals obturated with AHP, EndoSeal, ESBCS, MTA Fillapex, or left unfilled as a negative control (n = 6 for each group).	-EndoSeal, ESBCS and AHP showed a cell viability like the negative control group (P>0,05) but MTA Fillapex sealer was cytotoxic(P<0,05). -Varying production of IL-1β, IL-6, and IL-8 detected in all samples.	In this study with 3D cell culture, AHP, EndoSeal, and ESBCS were cytocompatible with the host tissues.

		Cytocompatibility of the materials assessed using the MTT assay. -Production of IL-1β, IL-6, and IL-8 studied using the ELISA. -One-way ANOVA performed, and significant differences analyzed using Duncan's multiple-range test. -Significance level set at α=0,05.		
«Retreatability of two endodontic sealers, EndoSequence BC Sealer and AH Plus: a micro-computed tomographic comparison». *Oltra e Al* *2017*	Observe the retreatment of two sealers, ESBCS compared with AHP using micro-CT analysis.	-56 human maxillary incisors divided into four groupe, instrumented and obturated using different techniques. -Micro-CT scans and digitized images used to analyze residual material volume. -Data analyzed with an ANOVA and a post-hoc Tukey test. Fisher exact tests used to analyze the ability to regain patency.	-Less residual root canal filling material observed in AHP groups retreated with chloroform in comparison to the other sealers. -ESBCS samples retreated with chloroform had better results than those retreated without the chloroform substance. -Patency could be re-established in only 14% of teeth in the ESBCS without the chloroform.	ESBCS group showed significantly more residual filling material than AHP regardless of whether both sealers were retreated with chloroform. (*Restor Dent Endod* 2017;42(1):19-26).
«Effect of different endodontic sealers and time of cementation on push-out bond strength of fiber posts». *Vilas-Boas et Al.* *2017*	Assess the effect of different endodontic sealers: ERBS AHP,an eugenol sealer, and BCBS ESBCS. The time of their cementation evaluated immediately or 7 days after the canal obturation on the bond strength with a fiberglass post celmented with RelyXtm ARC.	-Approved by the local ethics committee (CAAE 34892514.0.0000.5084). -Procedures performed by a specialist in endodontic treatments. Sealer preparations followed the manufacturers' instructions. -84 premolars divided into groups and subjected to different treatments. -The push-out test conducted on the post spaces of the root canals. Statistical analysis included two-way ANOVA,	-Type of endodontic sealer (P<0,001), time of post cementation(P=0,002) had a negative influence on bond strength of fiber-glass posts cemented with RelyXtm ARC. -AHP had the highest bond strength mean values regardless of the time of cementation. -Eugenol sealer showed lower bond strength than the AHP for the cementation time.	AHP: best sealer to obturate the root canal when fiberglass cementation with resin-based sealer is projected because it did not interfere with the fiber post bond strength. ESBCS is not a good alternative.

		Tukey's, and Dunnett's tests with a significance level of α =0,05.		
«Physicochemical Properties of Epoxy Resin-Based and Bioceramic-Based Root Canal Sealers». *Lee et Al* *2017*	Evaluate the physicochemical properties of 3 BCBS and of 3 ERBS. Flow, final setting time, radiopacity, dimensional stability and pH change studied.	-This study compared AHP, AD seal, Radic-sealer to ESBCS, Endoseal MTA, MTA Fillapex using physicochemical analysis. -Data analyzed using one-way ANOVA and Tukey's post hoc test).	-All sealers demonstrated a flow greater than 20mm except for ESBCS. -MTA Fillapex: highest flow and the BCBS had the lower flow. -EndoSeal MTA: longest setting time and RadicSealer and AD Seal had the shorter setting time than AHP(P<0,05). -AHP and EndoSeal MTA sealer showed statistically higher values and MTA Fillapex showed statistically lower radiopacity(P<0,05). -All sealers of this study showed radiopacity values complying with the ISO standards. -ESBCS: highest alkaline pH in all evaluation periods. -Set samples of 3 epoxy resin-based sealers and EndoSeal MTA presented a significant increase of pH over the experimental time for 28 days.	BCBS and ERBS showed clinical acceptable physicochemical properties, but ESBCS and MTA Fillapex were not set completely.
«Evaluation of the sealing ability of different root canal sealers: a combined SEM and micro-CT study ». *Huang et Al*	Explore the ability of various sealers to seal the dental tubules with the use of SEM and micro-CT and comparation of the sealing ability of the ESBCS and the AHP at the apical, middle, and	-24 human mandibular premolars instrumented, filled with either AHP or ESBCS using the single cone technique. -Micro-CT scans performed, and a subset of samples underwent SEM analysis. Porosity-related parameters measured using CTAn software.	-Both root canal sealers showed an acceptable adaptation to the dentin walls along the whole length of the root canal. Coronal sections presented superior sealing abilities than the apical sections. -Micro porosity analyses: the volume of closed pores and the surface of closed pores had the largest values in the coronal sections, followed by the	With the use of the single cone technique, neither ESBCS or AHP provides a porosity-free root canal filling. ESBCS reveal similar sealing abilities as the ERBS AHP. A better

2018	coronal level of dentinal tubules.	-Statistical analysis revealed significant differences between the groups.	middle and the apical sections for both sealers (P<0,05). -No significant difference observed for those parameters between AHP and ESBCS in any of the 3 sections (P>0,05), whereas they were larger in the apical section when the AHP was used.	sealing effect could be obtained in the coronal and middle sections of a root canal than the apical part by using any of those sealers.
«Clinical Outcome of Non-Surgical Root Canal Treatment Using a Single-cone Technique with Endosequence Bioceramic Sealer: A Retrospective Analysis». *Chybowski et Al* *2018*	Evaluate the outcome of a NSERCT with the use of a SCT obturation and with BCBS techniques.	-Retrospective cohort study conducted between 2009 and 2015 in a private practice setting examined the outcomes of patients treated with ESBCS. -Procedures performed using a surgical microscope. Patient and treatment factors evaluated as potential prognostic factors. Outcomes assessed based on clinical and radiographic findings at a one-year recall. Statistical analysis using the chi-square test(α=0,05) determined significant prognostic factors.	-307 teeth posteriors teeth were selected in this study and with a follow-up time of 30,1 months. -Process realized by 4 endodontists. -The success rate was 90,9%. Lesions<5 mm in diameter had a superior success rate than lesions>5 mm in diameter. -Patients younger than 50 years seemed to have a better rate success than the older patients. -The extrusion of the sealer observed in 47,4% of all the cases. -Presence of a sealer extrusion didn't have a significant effect on the outcome of the treatment.	ESBCS used with a SCT is a profitable sealer for obturation phase.
« Dentinal tubule penetration of AH Plus, BC Sealer and a novel tricalcium silicate sealer: a	Evaluate the dentinal tubule penetration of ESBCS and AHP and of a novel tricalcium silicate sealer (NTS).	-Study approved by the ethics committee of Saint Joseph University in Lebanon. -96 human maxillary central incisors filled with gutta-percha and one of three sealers: AHP, ESBCS,NTS. -Sealers prepared as instructed.	-Maximum and mean penetration depths higher at 5 mm compared to 1 mm from the apex in AHP	Within the study limitations, ESBCS and NTS demonstrated an enhanced tubule

confocal laser scanning microscopy study». *El Hachem et Al* *2019*		-Penetration measured using CLSM and ImageJ software. -Statistical analysis performed using SPSS.	(P<0,001), ESBCS (P<0,001) and then NTS groups (P<0,001). -No significant difference was determined between groups at 1 mm for all parameters. -Maximum and mean penetration depths lower at 5 mm for AHP compared with the other two groups (P=0,012).	penetration result than the ERBS AHP.
«Penetration of bioceramic and epoxy-resin endodontic cements into lateral canals». *Táccio de Miranda Candeiro et Al* *2019*	Estimate the capacity of penetration of the ESBCS and AHP in artificial lateral canals.	-Study approved by the Ethics Committee of Faculty São Leopoldo Mandic in Brazil, involved 26 maxillary first premolars with two roots and lateral canals. -Groups ESBCS and AHP compared, and sealers prepared according to manufacturers' instructions. Sealers penetration into lateral canals assessed by using digital periapical radiography. -Statistical analysis performed using Kruskal-Wallis and Student-Newman-Keuls tests (P<0,05).	-No significant difference noted between ESBCS and AHP used to obturate the simulated lateral canals (P>0,05). -ESBCS: better filling in the coronal third part of the root canal and AHP presented the best filling in the middle third part of the root of the canal. -The diameter of lateral canals only influenced the capacity of the ESBCS in the obturation of the canals and it presented greater penetration in the lateral canals with a diameter of 0,10 mm (P<0,05).	ESBCS: similar ability as AHP to fill simulated lateral canals. Diameter of the lateral canals impacted the filling when the ESBCS was used but the location of the simulated lateral canals had no significant impact and influence on the obturation capacity of the sealers used in this study.
«Outcome of Root Canal Treatments Using a New Calcium Silicate Root Canal Sealer: A Non-Randomized Clinical Trial». *Zavattini et Al* *2020*	Compare the success rate of NSERCT using BCBS for root canal BioRoot^{TM} RCS in combination with a SCT with a non-calcium silicate cement AHP and the WVT.	-150 necrotic pulpitis teeth by a specialist and trainees under supervision. -Canals obturated by using either the warm vertical technique (WVT) with gutta-percha or a calcium silicate-based sealer (BioRootTM RCS) with single cone technique (SCT) obturation.	-104 teeth assessed at 1 year recall (51 teeth=AH plus, 53 teeth = BioRoot^{TM} RCS). -The success rate used loose criteria for the CBCT images and PA radiographs and was respectively 80% and 89% in the AHP with the use of WVT group, 84% and 90% in the BioRoot^{TM} RCS/SCT.	BCBS with SCT resulted in a similar proportion of successful cases compared with WVT and the ERBS within the limitations of the study.

		-Follow-up assessment at 1 year conducted using CBCT, outcomes categorized as successful or failed. -Statistical analysis using Fisher's Exact test performed with a significance level of α=0,05.	-No statistically significant difference between the two groups (Fisher exact test P value 0,6099 in the CBCT images).	
«An Antimicrobial Activity Assessment of Three Endodontic Sealers on Enterococcus faecalis, Candida albicans, and Staphylococcus aureus by a Direct Contact Test: An In Vitro Study». *Chakraborty et Al.* *2020*	Estimate the antibacterial efficacity of 3 endodontic sealers in Enterococcus faecalis, Candida albicans and Staphylococcus aureus with the use of the direct contact test(DCT).	-Test of the efficacy of AHP, MTA Fillapex, ESBCS against E. Faecalis, C. Albicans, and S. Aureus using the direct contact test. -Sealers incubated, colony counts measured at 1 hour and 24 hours. Data analyzed using SPSS 16.0 with ANOVA, Tukey HSD test, and paired t-test. -Ethical clearance obtained from the I.T.S Institutional Ethics Committee.	-At both the time intervals DCT showed a significant decrease in microbial count in AHP, MTA fillapex, and ESBCS. -ESBCS showed a minimum microbial count followed by MTA fillapex and the maximum was for AHP. -AHP: no antimicrobial action against C.Albicans and Enterococci.	ESBCS has the best antimicrobial effectiveness against all the tested microorganisms for both the time intervals. MTA Fillapex and then AHP showed an efficacy lower than ESBCS. AHP has the worst efficacy in this present study.
«Micro CT pilot evaluation of removability of two endodontic sealers». *Colmenar et Al* *2021*	Compare the removability of AHP and ESBCS with the use of the Micro-CT.	-10 extracted human teeth cleaned and shaped with ProTaper NEXT rotary files. -Canals divided into two groups(AHP, ESBCS) and obturated with gutta-percha using the single cone technique. -After 90 days, ProTaper Universal Retreatment files used to remove the obturation materials. Micro-CT scans taken, percentage of material removed calculated.	-No statistically significant differences between these 2 sealers or among the sectional thirds within each group($P > 0,05$).	ESBCS and AHP: identical removability at all canal levels of 70% and 96%, with a better coronally removal. The removal is less effective in the apical portion of the tooth analyzed. These sealers can be removed equally using the PTR files. Residual sealer can be observed for both.

		-Statistical analysis included Shapiro-Wilk tests, Levene tests, two-sample t-tests, and one-way ANOVA.		
«Comparison of Postobturation Pain Experience after Apical Extrusion of Calcium Silicate– and Resin–Based Root Canal Sealers». **Drumond et Al** **2021**	Compare the intensity of the postobturation pain after an involuntary apical extrusion of ESBCS and Bio-C Sealer with a ERBS.	-330 patients that needing non-surgical endodontic root canal treatment for molar teeth with asymptomatic irreversible pulpitis. -Treatments performed by an experienced endodontist using WaveOne Gold instruments and irrigation solutions. Patients randomly assigned to three groups(AHP, ESBCS, Bio-C Sealer) for root canal sealer use. Technical quality of root canal filling and extruded sealer amount evaluated by blinded endodontists. Patients with unintentional sealer extrusion assessed for post-obturation pain at specific intervals. -Data analysis done using mixed analysis of variance repeated measures.	-Extrusion ratio similar for sealers (~12%). -No significant difference observed in the postobturation pain results between the root canal sealers evaluated($P > 0{,}05$). -No statistically differences regarding the sex, the age, or the tooth location in the arch between the sample inclusions of groups($P > 0{,}05$). -After a time interval of 12 hours, AHP(P=0,04073) and Bio-C Sealer(P=0,04327) demonstrated a significant reduction in pain. ESBCS didn't show differences in pain intensity($P > 0{,}05$).	The existence of unintentional apical extrusion of ESBCS presents similar postoperative pain results compared with AHP with low-intensity pain. (J Endod 2021;47:1278–1284.)
«Comparing the incidence of postoperative pain after root canal filling with warm vertical obturation with resin-based and sealer-based obturation with calcium silicate-based sealer: a prospective clinical trial». ***Yu et Al***	Compare the postoperative pain after a single-visit, NSERCT of teeth with an irreversible pulpitis with the use of two different root canal filling techniques.	-Study that compared two root canal treatment techniques(WVT with ERBS and SCT with calcium silicate-based sealer) in patients with irreversible pulpitis. -Pain intensity recorded postoperatively, and statistical analysis performed to compare the techniques.	-194 surveys distributed over 18 months. 92 patients returned the survey, 38% were asymptomatic with irreversible pulpitis cases. -No statistical difference noted between the 2 groups at the 3 time points assessed(P>0,05). -Postoperative pain referred to age, gender, presence of postoperative pain and to the sealer extrusion (P<0,05).	Intensity of the postoperative pain for the 2 obturation techniques with ESBCS and AH Plus Jet Root sealer was equivalent at evaluated time points.

2021			Not connected to preoperative periapical symptoms (percussion and/ or palpations): dent arch, root type, experience of the dentist (P >0,05).	
«Push-Out Bond Strength, Characterization, and Ion Release of Premixed and Powder-Liquid Bioceramic Sealers with or without Gutta-Percha». **Retana-Lobo et Al.** **2021**	Assess the push-out bond strength of premixed and powder-liquid bioceramic sealers (ESBCS) and ERBS (AHP) with the presence or the absence of gutta-percha cone.	-80 human teeth used to analyze the effects of different root canal sealers and obturation techniques. -Various analyses performed, and statistical analysis was conducted using three-way ANOVA and Tukey's test. -The significance level set at P<0,05.	-The result of the push-out bond strength showed that it was greater for samples obturated with only sealers (Group S) than samples obturated with the SCT (Group GP-S) (P<0,05). -BioRoo RCS showed a greater bond strength than the ESBCS. -Adhesive failures between sealer and gutta-percha cone (87,5%) were predominant in the group GP-S. -Cohesive failures for the group S (80%). -Sealers BioRoo RCS and ProRoot® ES revealed a higher alkalinization potential than the ESBCS. -Powder-liquid bioceramic sealers (BioRoot™ RCS and ProRoot® ES) presented the highest cumulative amount of calcium (28,46 mg/L and 20,05 mg/L).	A higher bond strength is revealed for the push-out test without the presence of gutta-percha cone with the use of BCBS. Thanks to the alkalinization potential and the calcium ion release, the powder-liquid calcium silicate-based ESBCS related a higher bioactivity than AHP.
«Coronal and apical leakage among five endodontic sealers». **Vo et Al** **2021**	Use dye penetration to gauge apical and coronal leakage in a single-canal tooth that has been treated endodontically with the use of the SCT obturation.	-100 human teeth worked with ProTaper NEXT rotary files and single cone technique with gutta-percha. -Rhodamine B dye used to assess sealer leakage. -Statistical tests conducted for analysis.	-Pairwise comparisons showed significant apical differences between AHP and Super-Bond RC Sealer (P=0,047), a significant coronal difference between AHP and NeoSEALER Flo (P=0,001), AHP and ESBCS (P<0,01), AHP and Super- Bond RC Sealer (P<0,01), Pulp Canal Sealer and NeoSEALER Flo (P=0,010), Pulp Canal Sealer and ESBCS(P<0,01), Pulp Canal Sealer and Super-Bond RC Sealer(P<0,01).	Apical leakage better than the coronal leakage for every sealer. AHP has the least leakage apically and coronally. Super-Bond RC Sealer showed the most leakage

		-Ethical approval obtained.		apically, and ESBCS the most leakage coronally.
«Physico-chemical properties of calcium silicate-based sealers in powder/liquid and ready to use forms». **Janini et Al** **2022**	Assess the physico-chemical properties MTApex Sealer (Ultradent) which is a prototype powder/liquid in comparison to the ready-to-use material. The paste/ paste ERBS AHP was the control group in this study.	-6 sealers observed for their sitting-time in environments with their moistures, flow, pH, and radiopacity, according to the ISO-6876/2012 standard. -Surface of material and chemical characterization assessed with use of scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). -Recommendations of preparation of sealers from the manufacturers respected. -Levene, Shapiro-Wilk, mixed ANOVA with JASP and post-hoc analysis with Bonferroni correction were realized at a significance level of 0,005.	-MTApex: highest flow. -ESBCS: longer setting time in dry compared to the moist environment. -With an additional moisture there is no changes for MTApex and AHP. -AHP: uniform matrix and particles. -Every material exceeded 7 mm Al of radiopacity and revealed a decreasing alkalinity after the 3 weeks of analysis.	Prototype powder/ liquid MTApex sealer showed the highest flow and almost the same sitting time in both dry and moist environments. ESBCS was influenced by the external moisture. MTApex can be more predictable.
«The Effect of Bioceramic HiFlow and EndoSequence Bioceramic Sealers on Increasing the Fracture Resistance of Endodontically Treated Teeth: An In Vitro Study». **Abdulsamad et Al** **2022**	Assess the root fracture resistance of the endodontically treated mandibular premolars teeth after preparing and filling with ESBCS, EndoSequence BC HiFlow, AHP.	-Study approved by the Ethics Committee of Damascus University involved 75 single-rooted mandibular premolars. -Teeth randomly divided into five groups for root canal preparation and filling. Different sealers used in each group. -Canals prepared using a glide path and filled with the respective sealers using the single cone technique. -After restoration, the samples subjected to a vertical force test to	-ESBCS and Endosequence BC HiFlow groups revealed a better fracture resistance (494,440 ; 496,960 N respectively) AHP group (492,680 N). -The greatest mean fracture force was observed in the positive control group (736,040 N) with statistically significant difference between the other groups($P<0,01$). -Least mean fracture force shown in the negative control group(318,040 N) with statistically significant difference between the other groups($P<0,01$).	ESBCS, EndoSequence BC HiFlow, and AHP enhanced the fracture resistance in root-filled single-rooted premolar teeth. The application of ESBCS, EndoSequence BC HiFlow, and AHP did not rise the fracture resistance of roots compared to that of unprepared root canals.

		measure fracture resistance. Statistical analysis performed using SPSS with a significance level of 0,05.		

Table 2: Table of results grouping together all articles used in this study.

5) DISCUSSION :

5.1. Chemical properties of EndoSequence BC sealer (Brasseler USA, Savannah, GA) and AH Plus (Dentsply De Trey Gmbh, Konstanz, Germany).

Composition

The precise proportions of the components are kept secret by their manufacturers, but it is possible to discover the form of presentation of the material and the names of its components.

EndoSequence BC sealer (Brasseler, USA, Savannah, GA) batch 19001SP is a bioceramic-based sealer (BCBS) and comes in one unit composed of (12–14):

- Tricalcium silicate
- Dicalcium silicate
- Zirconium oxide
- Calcium hydroxide
- Calcium phosphate monobasic
- Thickening agents

AH Plus (Dentsply, De Trey Gmbh, Konstanz, Germany) is an epoxy-resin-based sealer (ERBS) that comes in two components, a base and a catalyst (12–14):

The base is called « Paste A 1809000415» and is an epoxide paste composed of (12):

- Bisphenol-A epoxy-resin
- Bisphenol-F epoxy resin
- Zirconium dioxide
- Calcium tungstate
- Pigment
- Aerosil

The catalyst is called « Paste B 1809000318» and is an amine paste composed of (12):

- 1-adamantane amine N
- N'-dibenzyl-5-oxa-nonandiamin-1,9 TCD-Diamine
- Calcium tungstate
- Zirconium oxide
- Aerosol
- Silicone oil

The EndoSequence BC sealer is available in the pre-mixed form and in the ready-to-use form. AH Plus requires actions from the operator, to prepare it, it is recommended and advised by the manufacturers to mix Paste A and Paste B at a 1:1 ratio for a duration of 60 seconds. This mixture initiates a reaction with the formation of a high-molecular-weight addition polymer (12).

To activate EndoSequence BC sealer, which contains calcium silicate, hydration is necessary because without it, the reaction will not initiate. That's why the humidity and residual moisture in the dentinal tubules of the treated tooth are crucial for establishing the required contact between the sealer and the operating environment (12,14).

Ca^{2+} Release

The calcium content is important and made possible by the moisture in the dentinal tubules. Hydration reactions occur with the calcium silicates present in the sealer, the goal of the chemical reaction is to create calcium silicate hydrogel and calcium hydroxide. When in contact with phosphate-containing fluids for 2 months, the formation of an apatite layer is observed(14). Both the calcium silicates and phosphate partially react to form hydroxyapatite and water, enabling the hydration reaction of the silicates once again(14).

The hydration reaction formulas of di- and tricalcium silicate cements in contact with moisture are as follows (14):

(A) $2[3CaO.SiO_2] + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$

(B) $2[2CaO.SiO_2] + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + Ca(OH)_2$.

Reaction (A) $7Ca(OH)_2 + 3Ca(H_2PO_4)_2 \rightarrow Ca_{10}(PO_4)_6(OH)_2 + 12H_2O$.

The precipitation (A) allows the formation of an interfacial layer and develops a chemical bond between dentinal walls and the calcium silicate–based materials. It will be benefic for physical and biological properties (release of hydroxyapatite) of this sealer (14).

According to Candeiro et al.(14), EndoSequence BC sealer exhibited a stronger release of Ca^{2+} compared to AH Plus($P<0,05$). The presence of calcium ions varied at different experimental times, but there were no significant differences ($P>0,05$) between the two sealers after 24 hours.

EndoSequence BC sealer consistently showed a higher concentration of calcium ions than AH Plus throughout the experiment, with its calcium ion concentration being nearly three times higher than that of AH Plus at the end of the experiment (14).

pH

Sealers with an alkaline pH exhibit antibacterial properties, biocompatibility, and promote tissue formation. They activate alkaline phosphatase, neutralize lactic acid, prevent tooth mineral dissolution, and contribute to bone regeneration, enhancing overall oral health(13).

EndoSequence BC exhibited a higher pH value compared to AH Plus. Caution is necessary because setting a pH too high, above 12, can harm periapical tissue by causing loss of cell viability and membrane integrity (13). Consistent with Candeiro et al. (13), there is a correlation between the pH and the amount of Ca^{2+} released in both analyzed materials. The EndoSequence BC sealer maintains an alkaline pH throughout the experiment. AH Plus

exhibits a slightly neutral pH, indicating less potential for tooth tissue formation (12,14). The alkaline potential is more significant for EndoSequence BC (13,14).

Radiopacity

Radiopacity of sealers is important for assessing the quality of root canal fillings and detecting potential failures. Radiographic examinations and tomographic images help evaluate long-term outcomes and the adaptation of sealers to tooth structures. This information ensures effective root canal treatment and monitors treatment success(12–14).

The radiopacity of dentin is equivalent to 1,045 +/- 0,200 mm. According to the study of Candeiro et al.(13), the value of EndoSequence BC sealer (3,834+/-0,346 mm Al) was significantly lower (P<0,05) than that of AH Plus (6,936+/-0,462 mm Al) (14).

The radiopacity value of Endosequence BC sealer (3,83 mm Al) aligns with ISO 6786/2001, as the minimum accepted is 3,00 mm Al (13,14). In the study by Janini et al, ISO 6876/2012 recommendations are followed and according to them, sealers should have a radiopacity value above 7 mm Al, which is fulfilled by all the sealers analyzed in this study(12).

In both studies, the radiopacity value of AH Plus is greater than that of EndoSequence BC sealer(12,14).

The addition of radiopacifying agents to sealers increases their radiopacity, with bismuth oxide being the most effective followed by zirconium oxide, calcium tungstate, barium sulfate, and zinc oxide. AH Plus sealer, which contains calcium tungstate, has higher radiopacity compared to Endosequence BC sealer, which lacks radiopacifying agents.(12,14).

5.2 Biological properties of EndoSequence BC sealer (Brasseler USA, Savannah, GA) and AH Plus (Dentsply De Trey Gmbh, Konstanz, Germany).

Antimicrobial activity

Enterococcus faecalis is a bacteria present in the oral cavity that can cause persistent peri-radicular lesions if not properly eradicated and that can thrive in low-nutrient environments and survive as a mono-infection(15). Approximately 38% of failed root canal treatments are associated with it(15). Candida Albicans is another dentinophilic microorganism that can contribute to the failure of root canal treatment, while Staphylococcus Aureus is associated with refractory periapical disease(15).

AH Plus is now used as a sealer due to its biocompatibility and alkaline pH. EndoSequence BC sealer is used because of its composition, which includes calcium silicates and calcium hydroxide(15).

Chakraborty et al.(15) employed the agar diffusion test (ADT), it should be noted that this test cannot differentiate between bacteriostatic and bactericidal effects and is influenced by the diffusibility and solubility of the sealers in the agar. It is not suitable for assessing water-insoluble materials such as Endosequence Bc sealer. The direct contact test (DCT) methodology was used, which measures the effect of the tested microorganism and the material at the moment of contact based on microbial viability. Significant microbial count reductions were observed with EndoSequence BC sealer and AH Plus at both time intervals. EndoSequence BC sealer demonstrated maximum antimicrobial effectiveness against Enterococcus faecalis, followed by Candida albicans and then Staphylococcus Aureus (15,16). The active diffusion of calcium hydroxide may be responsible for the antimicrobial efficacy of EndoSequence BC sealer(15). AH Plus exhibited maximum antimicrobial efficacy against Enterococcus Faecalis, followed by Staphylococcus Aureus, while it did not show any antimicrobial effect against Candida Albicans(15).

It is challenging to reach a clear conclusion due to the varying results obtained from different studies. Here, AH Plus showed better efficiency than EndoSequence BC sealer against Enterococcus faecalis, possibly due to the methodology used in the study(15).

Agar diffusion test (ADT) revealed a more significant inhibition diameter for AH Plus (10,31+/-0,21 mm) compared to EndoSequence BC sealer (6,00+/-0,03 mm). The reliability of the agar diffusion test (ADT) is uncertain due to the diffusion capacity of the materials in the agar medium. The advantage of EndoSequence BC sealer is its shorter action time, as many bacteria are already killed after 24 hours. In this study, both sealers exhibited a similar action against bacteria without considering the time parameter(16).

The study by Chakraborty et al.(15) revealed that EndoSequence BC sealer and AH Plus are more efficient in terms of their antibacterial effects when freshly mixed, and their antimicrobial properties decrease over time(15).

EndoSequence BC sealer exhibits better antimicrobial efficiency than AH Plus at each selected time interval against Enterococcus Faecalis, Candida Albicans, and Staphylococcus Aureus. It is recommended to use EndoSequence BC sealer during the obturation phase to limit bacterial spread and eliminate as many bacteria as possible in order to prevent failures during nonsurgical endodontic retreatment(15).

Cytotoxicity, cytocompatibility and Genotoxicity.

Genotoxicity refers to the potential damage to cell DNA(16). When a genotoxic sealer meets host tissues, it can cause DNA damage in connective cells, delaying or impeding the healing process.

It is more advisable to use EndoSequence BC sealer during the obturation phase of non-surgical root canal treatment(16).

EndoSequence BC sealer consistently showed non-cytotoxicity towards host cells throughout the setting period, while AH Plus exhibited cytotoxic effects when freshly mixed and at higher concentrations. However, AH Plus became non-cytotoxic over time. Considering the cytotoxicity profiles of sealers is crucial for clinical decision-making. AH Plus sealer initially exhibits minimal cytotoxicity due to the release of formaldehyde from the added amines, but this cytotoxicity decreases after setting. After 14 days, both AH Plus and EndoSequence BC sealer show comparable growth of gingival fibroblasts, indicating

low cytotoxicity. However, to ensure avoidance of potential cytotoxic effects, it is recommended to use EndoSequence BC sealer directly(1).

The study by Da Silva et al. (16) used an ELISA to assess the production of immune system substances IL-1β, IL-6, and IL-8. Contrary to previous studies, they found that AH Plus and EndoSequence BC sealer did not exhibit cytotoxicity. This discrepancy may be due to the use of a 3D model that mimics in vivo conditions, resulting in lower concentrations of toxic substances and no observed cytotoxic effects in this case(16).

The inflammatory process is initiated and sustained by the upregulation of chemokines and proinflammatory mediators, IL-1β and IL-6 are involved in periapical tissue damage development, inducing osteoclastic differentiation and bone resorption, and leading to an inflammatory reaction and to a cytokine production(16). In Da Silva et al.'s study(16), the sealers of interest did not exhibit cytotoxicity under the experimental conditions using the 3D model. The production of cytokines was not disproportionate and did not indicate an immune system defense reaction(16).
Using EndoSequence BC may provide a greater safety margin due to its more biocompatible composition(1,15,16).

The pain

Postobturation pain caused by apical sealer extrusion is a common issue in endodontic treatment. Different sealers can have varying levels of neurotoxicity and contact with host tissues can lead to local inflammation and clinical pain symptoms in the peri-radicular area(6).
AH Plus sealer is associated with higher postobturation pain when there is sealer extrusion, while EndoSequence BC sealer shows better pain outcomes in such cases. Sealer extrusion is more common with EndoSequence BC sealer due to its solubility and penetration into dentinal tubules. Overall, postobturation pain does not significantly differ between these sealers, and the pain typically lasts 12 to 24 hours before subsiding(6). However, it can persist for up to two days after treatment(18). Patient characteristics such as gender, age, and sociocultural factors can influence pain perception. Men have higher pain tolerance, while older patients experience less pain. The warm vertical compaction technique (WVT)

results in a higher incidence of sealer extrusion compared to the sealer-based filling technique (SBT), but the pain experienced with both techniques does not significantly affect postoperative pain perception.(17).

EndoSequence BC may be more beneficial during contact with host tissues, there is no definitive determination of one sealer being superior to the other for postobturation pain(6).

5.3. Physical and mechanical properties ESBCS (Brasseler USA, Savannah, GA) and AHP (Dentsply De Trey Gmbh, Konstanz, Germany).

Solubility, flow, viscosity, and dimensional stability.

The solubility of EndoSequence BC sealer is close to the maximum limit allowed (2,9%+/-0,5) (ISO 6876/2001) and is the highest among the tested sealers. This can be attributed to its composition, which contains calcium phosphate and silicates, EndoSequence BC works in an environment with approximately 20% water content, its solubility is expected to be higher.

AH Plus sealer has lower solubility and viscosity compared to Endosequence BC sealer. Both sealers exhibit pseudoplastic behavior, with viscosity decreasing under higher injection force. Dimensional stability is crucial for effective sealing, and Endosequence BC sealer demonstrates minimal dimensional change. AH Plus shows dimensional changes primarily due to water sorption after polymerization(12,19).

Considering their comparable flow and dimensional stability values, both sealers can be used in non-surgicial root canal treatment. Endosequence BC sealer exhibits better solubility values(7,12,13,18).

Setting time and working time

The setting time of EndoSequence BC sealer after cementation and its interaction with time negatively affect bond strength(19). It is crucial to find the optimal setting time and ensure a fast-working time for better treatment outcomes.

EndoSequence BC sealer has a longer working time compared to AH Plus and exhibits a longer setting time in the dry method but no difference between the two methods for AH Plus(13,19). AH Plus demonstrates more efficient setting time as it is faster in both methods. The additional time required for EndoSequence BC sealer may be attributed to the hydration reaction, as epoxy-resin-based sealers are not dependent on moisture(12).
In terms of setting and working time, AH Plus appears to be superior to EndoSequence BC sealer.

Sealing ability, tubule penetration and thickness

A homogeneous and hermetic sealing is a crucial factor for the success of non-surgical root canal treatment, as approximately 58% of failures are caused by incomplete obturation(20).

EndoSequence BC sealer exhibits hydrophilic and thixotropic properties, allowing for good spreadability and wettability. It forms strong chemical bonds with dentin, ensuring effective sealing with minimal expansion. The warm vertical compaction technique affects the sealer's flow properties, while the single cone and lateral condensation techniques show comparable sealing abilities. Micro-porosity analysis and SEM observations indicate differences in closed and open pores, suggesting better penetration of bioceramic-based sealers into dentinal tubules(7,20,21).

The adhesion of sealers to dentin depends on the intermolecular surface energy and of the cleanliness of the dentin, as well as the wetting ability and the surface tension, which differ in coronal, middle, and apical sections. Smear layer removal is important as it prevents sealer penetration into dentinal tubules. The location of canals in dental roots does not significantly influence the success of root filling, but coronal sections exhibit better adaptation compared to apical sections(7,20).

EndoSequence BC sealer is an ideal sealant with bioactivity and biocompatibility, containing nanoparticles that facilitate penetration into dentinal tubules. AH Plus exhibit adhesion to dentin, good spreadability, and a light grip reaction, but being acidic, it may limit its bonding to dentin. Its polymerization can result in sealant cracking and deterioration(21). EndoSequence BC may be better suited for sealing lateral canals due to its greater

flowability, providing optimal sealing(7). Its dentinal tubule penetration may be superior(8). EndoSequence BC sealer exhibits better thickness than AH Plus and reveals more regions with gaps and a better sealing effect can be achieved in coronal and middle sections compared to the apex better sealing effect can be attained in the coronal and middle sections than in the apex, the differences between coronal and apical regions may be attributed to the lower diameter and density of dentinal tubules in the apical parts, which could explain the increased porosity of the middle and coronal regions in open pore areas (7,18,20,21).

Push-Out Bond Strength (with or without gutta-percha) and Characterization.

AH Plus demonstrates higher push-out bond strength compared to EndoSequence BC sealer when used with gutta-percha cones thanks to the covalent bonds between the epoxy resin and the amino group of collagens in dentin, resulting in a stronger bond between the sealer and the host cells (22). Better results are obtained when the sealer is used alone without gutta-percha cones, as bond strengths are higher with EndoSequence BC sealer. Plastic deformation of gutta-percha cones can lead to failures and negatively impact the push-out bond strength during obturation with AH Plus (22). Obturation with gutta-percha cones is more effective with AH Plus, while the outcome is similar with the appropriate technique for each sealer (19,22). Surface characterization reveals that EndoSequence BC sealer has a uniform matrix with small particles interspersed, with calcium representing the highest weight percentage of atoms (12), AH Plus exhibits a uniform matrix with interspersed particles of different sizes. When the sealer is used alone without gutta-percha cones, bond strengths and results are higher with EndoSequence BC sealer. When gutta-percha cones are used, AH Plus is more efficient.

Leakage

The chosen obturation technique can influence the degree of sealing and clinical outcomes (9). The simplest and widely used method, especially with BCBS (bioceramic-based sealers), is the single cone technique (SCT), which involves the use of matched-taper gutta-percha points and Niti instruments (9). AH Plus exhibited weaker leakage at both the coronal and apical sides, which gradually decreased during polymerization, reducing the risk of leakage. This sealer can penetrate into dentin tubules due to its fine particles and resin composition

(9). The sealing abilities AH Plus were stronger than those of EndoSequence BC sealer, that exhibited superior dye penetration compared to AH Plus when used with cold warm compaction technique (CWCT) (9). Evaluating dye leakage with the sealers used in single cone technique (SCT), coronal leakage was found to be worse than apical leakage for both sealers (9).

AH Plus remains the "gold standard" treatment, even with single cone technique (SCT), as it exhibited the least apical and coronal leakage. EndoSequence BC sealer showed more coronal leakage; however, both sealers can be successfully used to prevent coronal and apical leakage (9).

Fracture resistance

It is believed that teeth undergoing non-surgical endodontic root canal treatment are weaker and more susceptible to developing fractures compared to vital teeth. The chemo-mechanical preparation of the root canal can result in excessive removal of dentin tissue and prolonged exposure to irrigants, which can weaken the tooth (11). In a study by Topçuoglu et al. (11), teeth treated with EndoSequence BC sealer exhibited a better fracture resistance compared to those treated with AH Plus. AH Plus can increase fracture resistance in instrumented root canals. EndoSequence BC sealer and its chemical bonding can enhance fracture resistance through deep penetration of nanoparticles into canal irregularities, dentin tubules, and lateral canals (11).

EndoSequence BC sealer may have slightly better fracture resistance, but the overall outcome with both sealers is similar (11). It should be noted that the application of these sealers does not increase fracture resistance compared to untreated root canals (23).

Root canal retreatment

EndoSequence BC sealer leaves more residual filling material in the root canal compared to AH Plus (2,5). AH Plus is soluble in chloroform (99%), making it easier to remove than EndoSequence BC, regardless of whether chloroform is used. Chloroform can also enhance the removal of root filling material when used with Endosequence BC sealer (2). Chloroform exhibits antimicrobial activity against Enterococcus Faecalis, which is beneficial for

optimizing root canal disinfection (2). EndoSequence BC demonstrates stronger adhesion to dentin compared to other sealers, and its intratubular penetration is greater, that can explain the presence of residues during retreatment (5). While both sealers can be removed in equal proportions in the coronal third, EndoSequence BC sealer is more challenging to remove in the apical region (2). According to Colmenar et al. (5), the amount of remaining filling material in the apical part of the root canal is similar for both sealers. Hyunsuk et al. (25), eported that AH Plus exhibits slightly deeper penetration into dentin compared to EndoSequence BC sealer (24). Complete removal of filling materials is impossible as dentists typically need to remove 40% to 60% of additional root dentin to eliminate the sealer entirely (24). Conclusions regarding the ease of removal and retreatment characteristics of both sealers are not unanimous, as some studies suggest similar abilities and characteristics (5,24).

5.4. Estimation of the ease of use of the sealers for the dentist. Non-surgical endodontic root canal treatment outcome with EndoSequence BC sealer and AH Plus.

Dentists can also seek comfort when choosing a sealer through the presentation form of the sealer, such as whether it is pre-mixed or not, requires heat or not, and whether it is ready to be injected or not, as well as the working time it offers.

The pre-mixed sealer EndoSequence BC sealer is easier for dentists to use and reduces the risk of failures during sealer preparation. AH Plus Jet sealer is a sealer AH Plus that comes already prepared, eliminating the need to mix two pastes. It is conveniently supplied in a syringe, ready for immediate use (11).

AH Plus can be used with heat, while EndoSequence BC sealer requires a cold obturation technique. There is also an alternative called EndoSequence Sealer Highflow, which is a variation of the original sealer and allows for warm vertical compaction (23).

Dentists have the freedom to choose the sealer presentation and obturation technique that they prefer and feel most competent with, without being constrained by a specific technique imposed by the type of sealer selected for the endodontic treatment.

The outcome with both sealers can be approached delicately. EndoSequence BC sealer has a bacteriostatic effect and potential for cementoblasts, which can lead to increased and

faster healing of endodontic infections (25). It possesses properties that favor a favorable outcome, including biocompatibility and slight setting expansion, which allow for the use of single cone technique (SCT) and improve the clinical efficiency of root canal obturation, thereby potentially increasing the success rate of the canal treatment (10,25). In a non-randomized clinical trial conducted by Zavattini et al. in 2020 (25), EndoSequence BC sealer used in combination with single cone technique (SCT) demonstrated a similar proportion of successful cases compared to epoxy-resin based sealers like AH Plus used with warm vertical technique (WVC) (25).

Considering the limitations and potential biases in the interpretation of the studies used in this SIR is important. Factors such as the study duration, tooth type, materials used, the practitioner involved, the duration of follow-up to obtain significant results, and external factors can influence the studies and limit their validity.

It is crucial to stay informed about advancements and nuances in the field of endodontics.

6) CONCLUSION

-EndoSequence BC sealer may not be the obvious choice as the best sealer for the obturation phase in non-surgical endodontic root canal treatment. While it possesses efficient chemical, biological, and physical properties and has gained popularity in clinical practice due to its ease of use, it is important to note that it is also expensive.
It would be beneficial to develop a sealer that combines the chemical and biological properties of EndoSequence BC sealer with physical properties like the setting and working time characteristics of AH Plus in a more effective manner.

-Both EndoSequence BC sealer and AH Plus can be found in different forms to provide comfort to dentists and facilitate a positive experience for patients and a satisfactory outcome.

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