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# Root Canal Sealers: Current Overview

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## Abstract

The composition and characteristics of endodontic sealers for non-surgical root canal therapy (NSRCT) vary widely. According to their composition, characteristics, and kind of setting reaction, the following endodontic sealers are covered in this thorough review: silicone, epoxy resin, tri-calcium silicate, glass ionomer, zinc oxide-eugenol, salicylate, fatty acid, and methacrylate resin sealers. Temperature, solubility, aspects including tooth cytotoxicity, bio-compatibility, antibacterial activity, and sealing ability are critical to endodontic sealers' effectiveness. The relative degree of micro-leakage among all the pertinent sealers was determined by means of a meta-analysis of pertinent research because sealing ability is crucial to effective outcomes. The lowest relative microleakage among the sealers evaluated is found in tricalcium silicate sealers, which are followed by silicone sealers and other epoxy resin sealers that are not AH Plus. In addition, to having the best antibacterial action, tri-calcium silicate sealers are very bio-compatible. The goal of future sealers should be to combine medicinal benefits with a hermetic seal.

**Keywords:** endodontic sealers, biocompatibility, sealing ability, dentin-sealer interface, root canal sealers

## Introduction

Sufficient obturation of the prepared root canal space is a crucial component of successful root canal therapy in endodontic practice. It is commonly known that in order to create a fluid-tight seal and stop bacteria and their toxins from leaking into the periapical tissues, cement of some kind is needed when filling root canals with solid core material. This cement fills the small spaces between the core material and the canal's dentinal wall.[1,2]

Root canal sealer and Gutta Percha core filler material are the two primary ingredients that obturate the root canal space. The best biocompatible material for filling the radicular space is gutta percha. However, this material merely adapts to the neighboring dentinal walls; it is insufficient on its own to create and guarantee a tight seal of the root canal system. In order to fill in the small space discrepancies, auxiliary canals, and abnormalities inside the canal, as well as to adjust the obturating material to the root canal walls, root canal sealers are binding agents. Ørstavik claims that sealers are crucial for both filling inaccessible regions of the root canal system and sealing it with entombment of any residual bacteria. Solid obturating substance and sealer work together to produce a hermetic seal.[3,4]

Choosing the right sealer can affect how well endodontic therapy turns out. Given the wide range of commercially available root canal sealers, it is crucial to have a solid understanding of their composition and characteristics before choosing one for a given clinical scenario. The present review highlights root canal sealers in nutshell.

**Evolution Of Root Canal Sealers**

Historically, many materials have been used to fill root canals : [5,6,7]

1. **1800s and before** - Various materials ranging from tin foil, lead foil, gold foil, cotton pellets with various medicaments, wood, spunk, plaster of Paris, oxychloride of zinc, oxyphosphate of zinc, zinc oxide, paraffin, copper points, and various other concoctions were used to fill root canals.
2. **1809** -Hudson Filled pulp cavity with gold; anterior teeth only,
3. **1847** -Gutta-percha, ‘‘Hill’s Stopping’’& Edwin Truman introduced Gutta-percha, as filling material.(Which consisted of bleached gutta-percha and carbonate of lime and Quartz, the advent of gutta-percha as a root canal filling material in endodontics began)
4. **1867**- G. A. Bowman of St. Louis was credited with using gutta-percha points to obdurate root canals
5. **1867**- Bowman popularized the use of gutta-percha for filling root canals.
6. **1890**- Gramm Introduced copper points for filling root canals; later gold-plated them to prevent discoloration
7. **1895**-Stevens Marketed the wooden points for ‘‘pulp knocking’’
8. **1897**- Tomes Suggested paraffin for filling root canals
9. **1901**- Buest Recommended that gutta-percha has a core of a silver wire to provide rigidity
10. **1911**- Callahan presented his rosin-chloroform technique for filling root canals. He advocated this as a means to penetrate and to seal the dentinal tubules to provide a better hermetic seal.
11. **1912**- Prinz recommended a high melting-point paraffin for filling root canals
12. **1920**- Hermann began using calcium hydroxide mixture, called Calxyl, for filling root canals.
13. **1925**- Husband Suggested copper amalgam for filling root canals.
14. 1925- Rickert proposed the use of a cementing medium, or sealer, in conjunction with gutta-percha.

15. **1929-** Grove Made precision-fitting gold cones for obturation (canals were prepared with a special set of engine reamers)
16. **1929**- Trebitsch Introduced silver cones for root canal fillings
17. **1930**- Stewart Introduced a gold-tin amalgam for root canal filling
18. **1931**- Rickert was developed the original zinc oxide eugenol cement as a root canal sealer
19. **1933**- Jasper Introduced silver points that had the same diameter and taper as the root canal instruments.
20. **1936**- Grossman's non-staining ZOE formula appeared as a sealer that afforded more working time.
21. **1940** -The first clinical use of calcium hydroxide as a root canal–filling material was probably by Rhoner.
22. **1952**- Biocalex, a calcium oxide based sealer was introduced by Bernord.
23. **1954**-AH26-Epoxy resin based sealer recommended by Andre Schroeder in Switzerland
24. **1955**-Scheufele introduced resin based Diaket as a sealer.
25. **1960**-Wichterle and Lin introduced a plastic material Hydron.
26. **1961**-Tubliseal was introduced with a slight modification to Ricket's formula.
27. **1965**-Nyborg and Tullin gave a formula of Kloropercha.
28. **1973**-$N_2$ a relatively recent formula by Sargnti was introduced for root canal purpose.
29. **1976**-Ailford recommended endodontic glass iononmer ketac-endo as a root canal sealer.
30. **1984**-Silicone was introduced as root canal sealer.
31. **1991**-Ray & Seltzer – ketac endo
32. **1993**-MTA developed by Dr.Torabinejad.
33. **2004**- Resilion by Pentron clinical laboratory.
34. **2009**-Bioceramic based sealers- iroot SP, Endosequence BC sealer
35. **2010**-MTA based sealer.

**Definition:**[6]

Root canal sealers are Cements or Resins in a Semi-liquid or Plastic state which are used as binding agents to adhere to the root canal wall,bind the obturating material to the root canal wall as well as fill up the minor discrepancies between root canal and obturating material.

**Functions of root canal sealers:**[7]

1) **Binding agents** – They form a bond between obturation material and the dentinal walls.
2) **Antimicrobial Agents** – Some of the sealers possess antibacterial activity.
3) **As a filler** – Sealer fills the discrepancies between obturating material and the canal walls.
4) **As a lubricant**- It acts as a lubricant when used in conjuction with the solid core material like guttapercha.
5) **Radiopacity** – is a property rather than a function which disclose the presence of auxillary canals, resorptive areas, root fractures and the shape of the apical foramen.

**Ideal Properties of Root Canal Sealers**

Louis Grossman listed the following 11 requirements for a root canal sealer:[5]

1. It should be Tacky when mixed to provide good adhesion between core and the canal wall when set.
2. It should provide a Hermetic seal.
3. It should be Radiopaque so it can be visualized in the radiograph.
4. The particles of powder should be very fine so they can mix easily with the liquid.
5. It should Not Shrink upon setting.
6. It should Not Stain tooth structure.

7. It should be Bacteriostatic or at least not encourage bacterial growth.
8. It should Set Slowly.
9. It should be Insoluble in tissue fluids.
10. It should be Tissue Tolerant, that is, Nonirritating to peri-radicular tissues.
11. It should be Soluble in a common solvent, if it is necessary to remove the root canal filling.

    One might add the following to Grossman's original basic requirements:
12. It should not provoke an Immune Response in peri-radicular tissues.
13. It should be neither Mutagenic nor Carcinogen**.**

**Classifications of Root Canal Sealers** [5,6,8,9,10]

There are a number of classifications of root canal sealers which may be broadly classified & discussed as:

**A. According to Ingle**

**I. Cements**

**II. Pastes**

i. Chloropercha
ii. Eucapercha
iii. Kloroperka Ǿ

**III. Plastics and resins**

a) Diaket
b) AH 26
c) AH plus
d) Glass ionomer sealers

**IV. Experimental sealers**

i. Bis GMA
ii. Pit and fissure sealants
iii. Isopropyl cyanoacrylate
iv. Polyamide varnish
v. Dentine bonding agents

**B. According to Cohen and Burns**:

Endodontic sealing materials are classified according to revised (ADA & ANSI) specification no. 57 as follows:

**Type I** - Sealer cements to be used with core material

**Class I** -Includes materials with Powder and Liquid, that set through Non Polymerizing Process

**Class II** Includes materials with in the form of Two Pastes that set through Non Polymerizing Process

**Class III** Includes Polymer and Resin Systems, that set through Polymerization

**Type II**- Intended for use with or without core material or sealer

**Class I** Powder and liquid non polymerizing,

**Class II** Paste and paste non polymerizing,

**Class III** Metal amalgams

**Class IV** Includes Polymers & resin system polymerization

**C. According to FJ Harty:**

1) Zinc oxide eugenol based
2) Resin based
3) Gutta-percha based
4) Dentine adhesive materials
5) Materials with medicaments

- Paraformaldehyde
- N2
- Endomethasone
- SPAD
- Calcium hydroxide

**D. According to Grossman**

1. Zinc-oxide resin cements
2. Calcium hydroxide cements
3. Paraformaldehyde cements
4. AH 26
5. Diaket
6. Pastes -consist of a base of Zinc oxide and various chemical agents such as iodoform, thymol iodide, camphorated phenol and formaldehyde.

**E. According to Clark**

**I. Absorbable:**

a) Kerr sealer (Rickert)
b) Grossman's sealer
c) Roth root canal cement
d) Tubliseal
e) Tubliseal EWT
f) Sealapex

**II. Non-Absorbable:**

i. Diaket
ii. AH Plus
iii. Ketac Endo

**III. Based on composition**

**a) <u>Eugenol containing:</u>**

**i) Silver containing -**

- Kerr sealer
- Procosol

**ii) Silver free-**

- Procosol non-staining
- Grossman's sealer
- Tubliseal
- Wach's paste

**b) Non-Eugenol containing:**

- Diaket
- AH-26
- Kloroperka
- Eucapercha
- Nogenol
- Hydron
- Endofil
- Glass Ionomer
- Calcium phosphate
- Cyanoacrylates
- Polycarboxylates
- Medicated
- N2
- SPAD
- Iodoform paste
- Diaket
- Riebler's paste
- $Ca(OH)_2$ paste
- Mynol cement
- Endomethasone

**Eugenol sealer cements:** [11,12]

Zinc oxide and eugenol sets because of a combination of physical and chemical reactions, yielding a hardened mass of ZnO embedded in a matrix of sheath like crystals of Zn Eugenolate. In this chelation reaction two molecules of Eugenol (HE) react with Zinc oxide ZnO to form zinc eugenolate ($ZnE_2$). Water acts as an accelerator. This autocatalytic reaction can be presented as follow:

$$ZnO + H_2O \longrightarrow Zn(OH)_2 \longrightarrow Zn(OH)_2 + 2\,HE \longrightarrow ZnE_2 + 2H_2O$$

Base Acid Salt

The percentage of water, particle size of ZnO, the pH and additives are all important factors in setting reactions. The set cement consists of a matrix of zinc eugenolate that binds the unreacted zinc oxide particles together. On hydrolysis, zinc oxide form zinc hydroxide .This will react with acid eugenol to form eugenolate, with water being released. Here water is required for initiation of reaction & is also a byproduct of the reaction. Hence this type of reaction is known to be autocatalytic.

Practically all ZoE sealers cements are Cytotoxic and irritate on inflammatory response in connective tissue

**Manipulation:** [13,14]

Root canal cement is mixed on sterile glass slab with spatula slab can be sterilized by alcohol scrub and dried. Two or 3 drops of liquid is used and a slowly small increment of cement powder is added to the liquid and spatulated to a smooth creamy consistency.

Proper consistency of mix can be tested by 2 methods.

Drop test - In drop test, the mass of the cement is gathered on to the spatula and held edgewise, the cement should not drop off the spatular edge in less than 10-12 seconds. A no.25 reamer as file is rotated in the mass of cement; it is withdrawn and held in a vertical position. Correctly mixed cement should remain with very little movement on the blade of the instruments for 5-10 seconds.

String out test- In string out test, the mass of the cement is touched with flat surface of the spatula and is raised up slowly from the glass slab. The cement should string out for at least one inch without breaking.

**New Delivery system- AH Plus Jet™ Mixing Syringe:**

An automatic mixing tip that combines the sealer ingredients is included with the AH Plus Jet. It has a rotating and angularly movable intraoral tip that may be adjusted to suit different anatomic situations. Therefore, the sealer can be applied directly into the root canal orifices with AH Plus Jet. One hand is all that is needed to apply the sealer effectively. When used directly intraorally, the AH Plus Jet Mixing Syringe can be handled with a sterile, single-use Disposa Shield® Sleeve to prevent infection.[15]

To date, four generations of methacrylate resin–based sealers have been introduced:

| | |
|---|---|
| First generation | Hydron (Hydron Technologies, Inc,Pompano Beach, FL) -mid-1970s. |
| Second generation | EndoREZ (Ultradent Products Inc, South Jordan, UT) |
| Third generation | 1.FibreFill R.C.S. root canal sealant (Pentron Clinical Technologies,Wallingford, CT)<br>2.Resilon/Epiphany/Realseal (Resilon Research LLC,Madison, CT) |
| Fourth generation | 1. Meta- SEAL, Parkell Inc; RealSeal SE,SybronEndo)<br>2. 4-META-(4-methacryloyloxyethyl trimellitate anhydride) |

Properties of Root canal sealers:[16,17]

**Physical Properties of Zoe**

**1. Effect of powder: liquid ratio**

The characteristics of zinc oxide–eugenol-based root canal sealers are impacted by variations in the powder/liquid ratio. Higher powder to liquid ratios improve the zinc oxide eugenol sealer's working time, setting time, and radiopacity; they also lower the sealer's flow and eugenol release. There are no notable dimensional alterations as a result.

**2. Working time**

Kerr pulp canal sealer: It dissolves in 15 to 30 minutes and reduces inflammation by using a powder-to-liquid ratio of 1:1 for regular setting. In contrast to pulp canal sealer, which has a 6-hour working time, it takes 24 to 36 hours to set entirely. Regular working hours for Tubliseal are five minutes inside the root canal and twenty minutes on a glass slab. The extended workday lasts for eighty minutes. Even in the presence of dampness, the working duration is less than half an hour. ROTH 801 operates for 80 to 90 minutes.The Wach sealer has a moderate operating time.

**3. Setting time**

Procosol has setting time of less than 10-30 minute on glass slab while in the root canal it is 10-30 minutes due presence of moisture.

Grossman sealer has setting of 2 hrs at 37 degree and at 100% humidity while in the root canal 10-30 minutes.

**Tubliseal** 11 to 260 min

**Kerr PCS** 7 to 1405 min

**Procosol NS** 70 min to 2 weeks

**Pure ZOE** 163 to 300 min

**Roth 801** 8wks

4. **Setting Expansion:** GP increased volumetrically as the eugenol ratio in the sealer increased.
5. **Setting shrinkage:** The zinc ion of the zinc oxide and eugenol undergo a chelation reaction to form the setting reaction of ZOE-based sealers. The zinc oxide phase of GP and the calcium ions of dentin may potentially be involved in this process. This could be the reason why the ZOE-based sealers have less setting shrinkage.
6. **Solubility and disintegration:**

According to Wilson (1976), sealers based on zinc oxide exhibit a significant reduction in weight after 24 hours, with a high degree of solubility ranging from 5.74 to 9.27%. This results from the hydrolysis reaction of the hardened zinc eugenolate and the leaching of eugenol. Since the zinc oxide eugenol in saliva has been exposed for more than 72 hours at pH 4.5, it has a higher solubility. This is most likely caused by the hydrolytic product (ZnOH) that is produced when zinc oxide eugenol degrades. In an acidic environment, the hydrolytic products (ZnOH) are soluble, but nearly insoluble in a neutral pH.The sealing qualities are also impacted by the increased solubility.

7. **Adhesion:** Due to the limited adherence of gutta-percha to zinc oxide eugenol, a gap exists between gutta-percha and sealer, which further results in poorer seal qualities.
8. **Shear bond strength:** The gutta percha and the zinc oxide eugenol-based sealers have a stronger binding than the dentin. This is because the ZOE mixture undergoes a setting reaction that produces zinc ions and zinc oxide. Along with the calcium of the mineral phase of the dentin, this chelation process also takes place with the zinc oxide phase of the gutta percha. Eugenol is also a solvent of gutta-percha, which may soften it and strengthen the binding between it and the sealer by creating an electrostatic double bond between two eugenol molecules and one zinc molecule.
9. **Radiopacity:** The radio-opacity of one millimeter of zinc-oxide eugenol cement is slightly lower than that of gutta-percha, and it corresponds to 4-5 mm of aluminum. As the ratio of powder to liquid increases, the radiopacity of zinc-oxide eugenol cement increases by 40%. Since, pulp canal sealer contains silver too, it exhibits increased radiopacity.
10. **Flow:** When compared to other root canal sealer families, the zinc oxide–eugenol-based sealers have good flow qualities of about 40mm flow.Gutta-percha transmits a larger pressure to a sealer than to a liquid sealer, a higher powder/liquid ratio reduces the flow of sealers by 25%.
11. **Film thickness:** The thickness of the sealer coating is increased by a larger powder/liquid ratio. Thin layers of Pulp Canal Sealer EWT less than 50 µm are known to produce a better apical seal than thick layers, and the pressure transferred by the gutta-percha core reduces the thickness of the root canal sealer.

- **Biologic Properties Of Zoe:**[18-20]

1. **Cytotoxic and neurotoxic effect**

Free eugenol, a hazardous component of freshly mixed zoe sealer, can leak out and have a variety of deleterious effects on human gingival fibroblasts, osteoblast-like cells, and periodontal ligament cells. Free eugenol has neurotoxic effects as well. Haseih et al. did note, however, that eugenol leakage into periapical tissues is extremely minimal and drastically diminishes over time. Whereas Tubliseal, Wach Sealer, and Procosol have mild cytotoxic effects but demonstrate fibroblast recovery

after 15 days, pulp canal sealer has moderate cytotoxicity at first but decreases after 3 days.

**2. Sealing effect**

Adhesion between GP and ZOE is weak because ZnOE sealers were less effective than other sealers because of their relatively high solubility.

**3. Anti-bacterial effect**

In comparison to other sealers, a ZOE sealer in the pulp chamber disinfected the dental tubules down to 250 μm and had good antimicrobial properties. According to Kaplan et al, procosol demonstrated antibacterial activity against Candia albicans at 40 days, Streptococcous mutans and Staphylococcus aureus at 20–40 days, and Actinomyces at every time interval.

**4. Effect of extrusion of sealer**

The American Dental Association states that overfilling beyond the radiological apex by more than 2 mm is a technical error that can be attributed to either a lack of an apical stop, excessive instrumentation, or poor measuring. In the connective tissues, the majority of root canal filling sealers cause an initial acute inflammatory reaction. However, as the cement reaches its final set, cellular repair occurs unless the cement breaks down further and releases one or more of its toxic components, which causes inflammatory changes in the periapical area. No significant paradigm shift in the biologic principles and techniques of root canal obturation has occurred, with the exception of a few experimental setups. The qualities of sealers are still necessary for gutta percha and its replacements to inhabit and seal the intricate root canal system. Manufacturers have, however, successfully created and marketed innovative endodontic sealers. Along with the rise in popularity of adhesive endodontics, bio-ceramic sealers have also gained attention. Their biocompatibility is crucial since the root canal sealers are in direct contact with peri-radicular and periapical tissues and arent shielded by an epithelial layer. One of the main concerns is their physical characteristics, which are related to the creation of an apical seal.

Despite their long-term effectiveness, traditional ZOE sealer cements have drawbacks, including the difficulty to manage microleakage, the solubility of sealers, and their incapacity to reinforce roots since they do not stick to dentin. Compared to other root canal sealers, glass ionomer-based sealer cements have a short working duration and present a challenge for re-treatment since the material sets extremely hard. Although calcium hydroxide-based sealer cements have good biocompatibility, their high solubility has caused some concern about potential long-term apical or coronal microleakage. Despite their useful physiochemical properties, these cements should only be used in endodontic accidents or challenging cases. Although polydimethyl siloxane sealers are biocompatible, dimensionally stable, and insoluble, they have weak adhesion and bactericidal properties.

The primary issue with resin-based sealers is the amount of shrinkage that occurs during setting, which might jeopardize the seal despite their superior radiopacity, adhesion to root dentine, and film thickness. Furthermore, during the polymerization of the methacrylate resin-based sealers, gaps are created along the dentin/sealer interface due to the particularly unfavorable cavity shape (i.e., C-factor) of root canals. Despite their lengthy setting period, MTA-based sealers are appropriate for use in endodontic mishap situations because they are biocompatible and bioactive.

In light of this evidence, the recent development of root canal sealer materials has been truly phenomenal, vis-à-vis the emergence of generations of Resin based sealers, MTA sealers and Bio-ceramic sealers. Nevertheless, there is paucity of evidenced based clinical information

available on some of aggressively promoted materials. Tri-calcium silicate sealers had the least amount of relative micro-leakage when compared to AH Plus, followed by silicone sealers and other epoxy resin sealers that were not AH Plus. Additionally, tri-calcium silicate sealers have the best anti-bacterial activity and superior bio-compatibility. It would be excellent for future sealers to combine medicinal benefits with a hermetic seal.

**Conclusion**

Determining whether a pulp is necrotic or viable is crucial when choosing an endodontic sealer for clinical application. In cases of vital pulpitis, non-surgical root canal therapy employing the asepsis method can be effective without medicated sealers. Sealers based on tricalcium silicate provide beneficial therapeutic benefits in cases of necrotic pulp, particularly those with considerable apical radiolucency. It is imperative for long-term clinical success to have a coronal seal by final permanent repair, regardless of the sealer used. The technical quality of the endodontic treatment is less significant for the health of the apical periodontal tissue than the technical quality of the coronal restoration.

**References**


1. Lee M, Winkler J, Hartwell G, Stewart J, Caine R. Current trends in endodontic practice: emergency treatments and technological armamentarium. J Endod 2009; 35: 35-39.
2. Coronal leakage – Clinical and biological implications in endodontic success. Endodontics Colleagues for Excellence 2002: 2-7
3. Hauman CH, Love RM. Biocompatibility of dental materials used in contemporary endodontic therapy: a review. Part 2. Root-canal-filling materials. Int Endod J 2003; 36: 147-160.
4. Ørstavik D, Kerekes K, Erkisen H. Clinical performance of three endodontic sealers. Endod Dent Traumatol 1987; 3:178–86
5. Grossman L.Obturation of root canal. In: Grossman L, ed. Endodontic Practice.10th ed. Philadelphia, PA: Lea and Febiger; 1982:297.
6. Cohen 'PATHWAYS OF THE PULP;10$^{TH}$ Edition.
7. Tyagi S, Mishra P, Tyagi P. Evolution of root canal sealers: An insight story. European Journal of General Dentistry. 2013 Sep;2(03):199-218.
8. R, von Fraunhofer JA. The properties of endodontic sealers. JOE 1988; 14:527.
9. Karobari MI, Parveen A, Mirza MB, Makandar SD, Nik Abdul Ghani NR, Noorani TY, Marya A. Root and root canal morphology classification systems. International Journal of Dentistry. 2021;2021(1):6682189.
10. Curson I, Kirk EE. An assessment of root canal-sealing cements. Oral Surgery, Oral Medicine, Oral Pathology. 1968 Aug 1;26(2):229-36.
11. Zhekov K, Stefanova VP. Definition and classification of bioceramic endodontic sealers. Folia Medica. 2021 Dec 31;63(6):901-4.
12. Abu Zeid ST, Mokeem Saleh AA, Khafagi MG, Abou Neel EA. Setting reaction of new bioceramic root canal sealers. Spectroscopy Letters. 2018 Sep 14;51(8):426-30.
13. Camargo CH, Oliveira TR, Silva GO, Rabelo SB, Valera MC, Cavalcanti BN. Setting time affects in vitro biological properties of root canal sealers. Journal of Endodontics. 2014 Apr 1;40(4):530-3.
14. Allan NA, Walton RE, Schaffer M. Setting times for endodontic sealers under clinical usage and in vitro conditions. Journal of Endodontics. 2001 Jun 1;27(6):421-3.

15. Rosa SJ, Duarte MA, Silva EJ, de Oliveira MC, Titato PC, de Vasconcelos BC, Vivan RR, Alcalde MP. Does the mixing method of AH Plus Jet affect its physicochemical and mechanical properties?. Journal of Endodontics. 2024 Sep 1;50(9):1333-9.
16. Flores DS, Rached-Júnior FJ, Versiani MA, Guedes DF, Sousa-Neto MD, Pécora JD. Evaluation of physicochemical properties of four root canal sealers. International endodontic journal. 2011 Feb;44(2):126-35.
17. Colombo M, Poggio C, Dagna A, Meravini MV, Riva P, Trovati F, Pietrocola G. Biological and physico-chemical properties of new root canal sealers. Journal of clinical and experimental dentistry. 2018 Feb 1;10(2):e120.
18. Saad AY. Physicochemical, cytotoxicity, and biological properties of calcium silicate-based root canal sealers: A literature review. Saudi Endodontic Journal. 2020 Sep 1;10(3):173-80.
19. Cardinali F, Camilleri J. A critical review of the material properties guiding the clinician's choice of root canal sealers. Clinical oral investigations. 2023 Aug;27(8):4147-55.
20. Özdemir O, Kopac T. Cytotoxicity and biocompatibility of root canal sealers: A review on recent studies. Journal of Applied Biomaterials & Functional Materials. 2022 Feb;20:2280800 0221076325.