"A Comparative Evaluation of Retreatability of Epoxy Resin, Silicone and Calcium Silicate Based Endodontic Sealers: An In-vitro Cone-Beam Computed Tomography Analysis"

By

REG. NO. IE0222001

Dissertation

Submitted to the
KLE Academy of Higher Education & Research Belagavi, Karnataka In partial fulfillment of the requirements for the degree of

MASTER OF DENTAL SURGERY
In
CONSERVATIVE DENTISTRY AND ENDODONTICS
(BRANCH – IV)

DEPARTMENT OF CONSERVATIVE DENTISTRY AND ENDODONTICS
KAHER's V K INSTITUTE OF DENTAL SCIENCES
BELAGAVI, KARNATAKA

2022 – 2025

KLE ACADEMY OF HIGHER EDUCATION & RESEARCH

BELAGAVI, KARNATAKA

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REG. NO. IE0222001.

Head of Department

Dr. SONAL B. JOSHI M.D.S
Professor & Head of Department,
Department of Conservative Dentistry and Endodontics,
KAHER V.K. Institute of Dental Sciences,
Belagavi.

Dr. Sonal B Joshi
Consultant : Regd.No. 27788-A
Conservative Dentistry & Endodontics
KLE VK IDS, Belgaum

Date: 14th APRIL 2025

Place: Belagavi

Principal

Dr. ALKA KALE M.D.S
Principal,
KAHER V. K. Institute of Dental Sciences,
Belagavi

PRINCIPAL
KLE V.K. Institute of Dental Sciences
Nehru Nagar, BELAGAVI-590010.

Date : 19/4/25

Place : Belagavi

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LIST OF ABBREVIATIONS

SR.NO	ABBREVIATIONS	FULL FORM
1	NaOCl	Sodium Hypochlorite
2	EDTA	Ethylene Diamine Tetra-acetic Acid
3	SP	Sealer Penetration
4	+	Plus
5	WL	Working Length
6	ANOVA	Analysis of Variance
7	SD	Standard Deviation
8	n	Number of specimens
9	p-value	Probability of obtaining a test statistic at least as extreme as the one that was actually observed
10	<	Less than
11	>	Greater than
12	μm	Micrometers
13	RCT	Root Canal Treatment
14	&	And
15	Grp	Group
16	ml	Milliliter
17	° C	Degree Celsius
18	mm	Millimeter
19	i.e.	That is
20	SE	Standard error
21	CBCT	Cone Beam Computed Tomography
22	PTR	Protaper Universal Retreatment
23	CWC	Continous Wave Compaction
24	LC	Lateral Condensation
25	WVC	Warm Vertical Compaction

ABSTRACT

Aim of the Study: To evaluate and compare the retreatability of root canals obturated with Epoxy resin, Silicone and Calcium silicate based sealer using Protaper

Universal Retreatment files and analysed

OBJECTIVES:

- To evaluate the retreatability of root canals obturated with Epoxy resin, Silicone, Calcium silicate based sealers using CBCT.
- To compare the retreatability of root canals obturated with Epoxy resin, Silicone, Calcium silicate based sealers using CBCT.
- Time taken for the complete removal of Epoxy resin, Silicone and Calcium silicate based sealers using stopwatch.

Study design: Forty five extracted human mandibular premolar single rooted teeth were selected and handled according to OSHA guidelines. The teeth were decoronated using a diamond disc under copious water spray to acquire a standardized root length of 14 mm from the apex. Working length was established 1mm short of the root length till 10K file exits the apical foramen. Cleaning and shaping was performed using Protaper Universal Rotary system till MAF F3. 2ml of 3% of Sodium hypochlorite was used as an irrigant, after each change of instrument. Final rinse was done by 17% ethylenediaminetetraacetic acid (EDTA) followed by saline. The root canals were dried by using paper points. Then, the samples were randomly divided into 3 groups based on the sealer used (n=15).

Group I: Epoxy resin-based sealer + Thermoplasticized gutta-percha

Group II: Silicone-based sealer +Thermoplasticized gutta-percha

Group III: Calcium silicate-based sealer +Thermoplasticized gutta-percha

The sealers were mixed according to the manufacturer's instructions and were coated on the canal walls, 1mm short of the apex using a No. 25 lentulospiral. Obturation was done using Continous Wave Compaction technique. Post obturation CBCT images were taken to check the quality of obturation. Samples with voids or incomplete obturation were discarded from the study and a new sample was added to the group. Teeth were sealed with Cavit and incubated at 37°C and 100% humidified conditions for 2 weeks. After 2 weeks, Cavit was removed with round bur, thus forming a reservoir for the solvent. Drop of Orange oil (GP solvent) was applied to the gutta-percha for 2-3 mins and a size 25 K file was used to establish a glide path before introducing rotary instruments. The obturating material was removed with Potaper Universal Retreatment system.The D1, D2 and D3 files were sequentially used at a speed of 500rpm. The retreatment files were utilized for the retreatment of a maximum of three canals. Each file was examined under magnification for any signs of distortion or fracture following use. Files exhibiting any visible deformation or structural compromise were immediately discarded to ensure standardization and procedural safety At each change of instrument, the root canals were irrigated with 2ml of 3% Sodium hypochlorite. When the instrument reaches apical one-third use of solvent was discontinued. The working length was maintained and root canals were reshaped using Protaper Universal rotary system to a MAF size F3. At the end of this procedure, all root canals were irrigated with 2ml of 3% Sodium hypochlorite, 17% EDTA, followed by final flush of saline and was dried with paper points. Retreatment time for

complete removal of obturating material was recorded using stopwatch. The samples were evaluated using CBCT in axial , coronal and sagittal sections.

CBCT cross-sections will be analysed and scores will be obtained for all the CBCT images by using formula: (S1/S2)X100

S1 is the surface area of the residual obturating material

S2 is the surface area of the root canal.

Results: Statistical analysis indicated that there were significant variations in the residual surface area of obturating materials, depending on the type of sealer used and the specific region of the root canal ($p < 0.05$). The apical third consistently showed the highest residue, while the coronal third had the least. Among the sealers, Ceraseal exhibited the highest residual material, indicating reduced retreatability. AH Plus showed moderate values, and GuttaFlow Bioseal demonstrated the least residue across all thirds, suggesting superior removal efficiency during retreatment.

Conclusion: The findings indicate that the efficiency of root canal retreatment is significantly influenced by the type of sealer used and the canal region. GuttaFlow Bioseal exhibited the highest retreatability, followed by AH Plus, while Ceraseal proved the most difficult to remove. The apical third remained the most challenging area for complete material removal, emphasizing the need for advanced techniques in this region.

Key words: Ceraseal, AH Plus, GuttaFlow Bioseal, Protaper Universal Retreatment system, Cone beam computed tomography, Orange oil, Continous Wave Compaction

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INTRODUCTION

Root canal therapy is considered a highly predictable and successful procedure, with reported success rates reaching up to 93%. However, in certain instances, treatment outcomes may be compromised, resulting in persistent apical pathology.[1] In such cases, non-surgical endodontic retreatment serves as the preferred intervention, with the primary objective of eliminating residual infection and re-establishing periapical health. This objective necessitates regaining access to the root canal system, followed by complete removal of the previous obturation material, thereby facilitating thorough chemomechanical debridement, disinfection, and subsequent re-obturation of the canal system.[1]

A major impediment to successful retreatment lies in the incomplete removal of obturating materials, particularly endodontic sealers. These remnants may act as a physical barrier, preventing disinfecting agents from reaching microorganisms located within inaccessible anatomical complexities. Moreover, residual sealer may adversely affect the adhesion of newly placed sealer to dentinal surfaces, potentially compromising the integrity of the coronal and apical seal. Previous studies have identified sealer remnants as the predominant component of residual filling material following retreatment procedures.[2] Root canal sealers are available in various formulations, including zinc oxide-eugenol-based, calcium hydroxide-based, glass ionomer-based, silicone-based, and resin-based types.[3]

AH Plus (Dentsply) sealer is one of the most widely used epoxy resin-based endodontic sealers. It consists of a paste-paste system i.e. Epoxide paste Diepoxide, Calcium tungstate, Zirconium oxide, Aerosil, Pigment., Amine paste- 1-adamantane amine,1-adamantane amine, TCD-Diamine, Calcium tungstate, Zirconium oxide,

Silicone oil.[4] This sealer recognized for its favorable physical characteristics such as low solubility, suitable flow, and the ability to establish an effective apical seal. Despite these advantages, it lacks the capacity to chemically bond with dentinal surfaces, which may affect the long-term integrity of the seal and pose challenges during retreatment. As a result, there is an ongoing interest in the development of alternative sealers that not only exhibit strong adhesion to root canal dentin but also allow for easier removal when retreatment is required.

GuttaFlow Bioseal (Coltene Whaldent), is a new Silicone based-sealer, a hybrid cement consisting of bioactive ceramic glass in a mixture of gutta-percha, polydimethylsiloxane, platinum catalyzer and zirconium dioxide.[1] This sealer has demonstrated low solubility and porosity, alkalization capacity, dentine penetrability and it also favours the regeneration of apical tissues.[1]

Calcium silicate (CS) materials, called Bioceramics, are considered a breakthrough in endodontic treatment due to their advantageous biocompatibility, antibacterial activity, appropriate filling ability, and good physicochemical properties. Premixed sealers demonstrated greater filling ability and easier application than conventional sealers.[5]

Ceraseal (Metabiomed, Korea) is a premixed calcium silicate based-sealer consists of Tricalcium silicate (Ca_3SiO_5) Dicalcium silicate (Ca_2SiO_4), Zirconium oxide (ZrO_2), Tantalum oxide (Ta_2O_5), Calcium hydroxide ($Ca(OH)_2$) and Thickening agents and dispersing additives. It demonstrates higher obturation quality and appropriate biological, mechanical, and physicochemical properties.[6]

A variety of obturation techniques have been developed to enhance the three-dimensional sealing of the root canal system. Among the most commonly employed methods are Lateral Condensation (LC), Warm Vertical Compaction (WVC), Continuous Wave Compaction (CWC), and thermoplastic injectable gutta-percha techniques.[7] A well-obturated root canal is characterized radiographically by a continuous radiopaque mass that conforms precisely to the shape of the canal without the presence of voids. To address the anatomical complexities of the root canal system—particularly in irregular or oval-shaped canals—thermoplastic obturation methods have gained widespread acceptance. Techniques such as CWC and other Thermoplasticized gutta-percha system involve heating gutta-percha above 60°C, which increases its plasticity and flow. This property facilitates better adaptation to canal irregularities, thereby producing a denser and more homogeneous fill.[8] Over time, several thermoplastic techniques have been introduced, including thermomechanical compaction, the CWC technique, and core-carrier systems, each offering improved outcomes in complex canal anatomies.[8]

One of the basic properties of an ideal root canal obturating material is being removable for retreatment purpose. For proper removal of root canal filling, many techniques and materials have been proposed including hand and rotary files, heat carrying instruments, solvents, ultrasonics and lasers. [9]

Grossman has quoted one of the basic requirement for an ideal root canal sealer is to be soluble in a solvent in case of retreatment .[4.] A variety of solvents are available for clinical use, including eucalyptus oil, orange oil, xylene, and chloroform. These agents play a dual role by dissolving gutta-percha and functioning as lubricants for endodontic instruments, thereby minimizing the risk of instrument separation, canal transportation, and root perforation during retreatment procedures. Among these

options, orange oil has gained preference due to its favorable biological profile. It has been shown to be less cytotoxic and more biocompatible compared to eucalyptol and chloroform, making it a safer alternative for both patients and clinicians.[10]

The use of rotary files successfully facilitates an effective removal of the bulk of gutta-percha and sealer based fillings from the root canal. Among the various systems developed, the ProTaper Universal Retreatment (PTR) system has been proven to be an effective retreatment system which includes three files D1, D2 and D3 with various tapers and tip diameters.[9]

Various methods have been utilized to assess the remnants of root canal sealers and gutta-percha following retreatment procedures. Among these, stereomicroscope, micro-computed tomography (micro-CT), and cone-beam computed tomography (CBCT) are the most commonly employed. Stereomicroscope allows for direct visual evaluation of the canal surface; however, it requires sectioning of the tooth, which is a destructive process and may compromise the integrity of the sample.[11] Micro-CT is considered the gold standard for three-dimensional assessment due to its high resolution and accuracy, yet its application is often limited by high costs, technical complexity, and limited accessibility in routine clinical practice. In contrast, CBCT has gained popularity in recent years owing to its non-invasive nature, greater availability, and lower radiation exposure compared to conventional CT. CBCT exhibited better efficacy compared to routine radiographic techniques. It provides a 3D view of the root canal non-invasively.[11]

The controversy on the removal of the new sealers i.e. Calcium silicate and Silicone based root canal sealers during retreatment is a matter of concern among many clinicians.(3) To our knowledge, no research was been done on comparison of

the retreatability of root canals obturated with Epoxy resin, Silicone and Calcium silicate based-sealers using Protaper Universal Retreatment files.

Therefore, the aim of this study was to compare the retreatability of canals obturated using AH Plus, GuttaFlow bioseal and Ceraseal sealers. The retreatment efficacy of these sealers using Protaper retreatment files, was assessed using CBCT.

AIMS AND OBJECTIVES

AIM

To evaluate and compare the retreatability of root canals obturated with Epoxy resin, Silicone and Calcium silicate based sealer using Protaper Universal Retreatment files.

OBJECTIVES

To evaluate the retreatability of root canals obturated with Epoxy resin, Silicone, Calcium silicate based sealers using CBCT.

To compare the retreatability of root canals obturated with Epoxy resin, Silicone, Calcium silicate based sealers using CBCT.

Time taken for the complete removal of Epoxy resin, Silicone and Calcium silicate based sealers using stopwatch.

HYPOTHESIS

NULL HYPOTHESIS: -

There will be no difference in the retreatability of Epoxy resin, Silicone and Calcium silicate based sealers using Protaper Universal Retreatment system

ALTERNATE HYPOTHESIS: -

There will be a difference in the retreatability of Epoxy resin, Silicone and Calcium silicate based sealers using Protaper Universal Retreatment system

REVIEW OF LITERATURE

1. An in-vitro-study by Sedigheh Khedmat et al, to compare the efficacy of ProTaper retreatment (ProTaper R) and Mtwo retreatment (Mtwo R) files in removing gutta-percha and GuttaFlow from endodontically treated straight root canals. In study they have used AH 26 and GuttaFlow sealer, filled canals with Lateral condensation obturating technique, retreatment was done using ProTaper retreatment (ProTaper R) and Mtwo retreatment (Mtwo R) files, without using any solvent, and CBCT was used for evaluation. The study concluded that the remaining filling materials in the canals treated with ProTaper were less than Mtwo. The remaining volume of GuttaFlow was less than gutta-percha regardless of the system applied. Mtwo R files removed root fillings faster than ProTaper R.

2. An in-vitro-study by Tamer Tasdemir et al. to assess the removability of canal fillings performed by using current methods during re-treatment with rotary instruments. The teeth were randomly divided into 4 obturation groups of 18 specimens each as follows: group 1, Resilon and Epiphany; group 2, GuttaFlow obturation system; group 3, EndoTwinn obturation system; group 4, gutta-percha with AH Plus sealer. The filled canals were re-treated by using Mtwo-Retreatment instruments and Mtwo instruments. Operation microscopes, have been used for evaluation purpose. In addition, the roots were split longitudinally, and the residual gutta-percha and sealer were measured with a scoring system or linearly. The study concluded that the residue of the root-filling materials was observed in all specimens regardless of the root-filling material used. When the filling amounts inside each third and the whole root canal were compared, there were no statistically significant differences between the filling methods ($P > .05$). After the removal of the material,

there were more filling remnants in the apical third compared with the middle and coronal thirds.

3. An in-vitro study by Emel Uzunoglu et al. to evaluate the retreatability of root canals obturated with gutta-percha (GP) and three different endodontic sealers [iRoot SP (bioceramic sealer), MTA Fillapex (MTA-based sealer) and AH-26 (epoxy resin-based sealer)] using the ProTaper Universal Retreatment (PTR) system. Evaluated under a stereomicroscope. The study concluded that in single-cone GP/MTA Fillapex group the Total working leghth (TWL) was significantly shorter. The remnant of filling material in the apical and middle thirds of groups was similar and higher than the coronal thirds. None of the tested sealers were completely removed from the root canal system

4. An in-vitro study by Valentina Giuliani et al. to evaluate the efficacy of the ProTaper Universal System rotary retreatment system and of Profile 0.06 and hand instruments (K-file) in the removal of root filling materials. Forty-two extracted single-rooted anterior teeth were selected. They were randomly divided into 3 experimental groups. The filling materials were removed with solvent in conjunction with one of the following devices and techniques: the ProTaper Universal System for retreatment, ProFile 0.06, and hand instruments (K-file). Evaluated under a stereomicroscope. The study concluded that the group that showed better results for removing filling materials was the ProTaper Universal System for retreatment files, whereas the group of ProFile rotary instruments yielded better root canal cleanliness than the hand instruments, even though there was no statistically significant difference. The ProTaper Universal System for retreatment and ProFile rotary instruments worked significantly faster than the K-file. The ProTaper Universal System for retreatment files left cleaner root canal walls than the K-file hand

instruments and the ProFile Rotary instruments, although none of the devices used guaranteed complete removal of the filling materials. The rotary NiTi system proved to be faster than hand instruments in removing root filling materials.

5. An in-vitro study by E. Pedulla et al. To investigate the retreatability of two calcium silicate-based materials (BioRoot RCS, Septodont, Saint-Maur-des-Fossés, France) and GuttaFlow Bioseal, (Colténe/Whaledent) using rotary instrumentation combined with supplementary irrigant agitation techniques using extracted teeth in a laboratory setting. Root canals were filled with gutta-percha and GuttaFlow Bioseal (GB, group 1) or BioRoot RCS (BR, group 2), scanned using a micro-CT scanner and stored in phosphate-buffered saline for 4 months. Removal of root filling was performed with rotary instruments, and specimens were randomly allocated to one of the subgroups for supplementary irrigant agitation (n = 12): subgroup A, syringe irrigation (control); subgroup B, Tornado Brush (M.I.B, Suresnes, France) and subgroup C, ultrasonically activated irrigation. Specimens were re-scanned with micro-CT to calculate the volume of remnant root filling material. The study concluded that Specimens filled with GuttaFlow Bioseal were associated with a significantly smaller volume of root filling remnants compared with BioRoot RCS ($P < 0.05$). In group 2 (BioRoot RCS), subgroups B (Tornado Brush) and C (ultrasonically activated irrigation) were associated with a significantly smaller volume of root filling remnants compared with subgroup A (syringe irrigation) ($P < 0.05$). There was no significant difference between subgroups B and C.

6. An in-vitro study byTamer M. Hamdy et al. to assess and compare the physicochemical properties of two bioceramic sealers—AH Plus Bioceramic Sealer and Bio-C Sealer—with the resin-based sealer ADseal. The parameters evaluated included flowability, setting time, solubility, and dimensional stability in accordance

with ISO and ANSI/ADA specifications.X-ray fluorescence (XRF) analysis was done for the chemical elemental analysis of each seale The results demonstrated that both bioceramic sealers exhibited adequate flow, acceptable setting times, and low solubility, meeting the required standards.

7. An in-vitro study by Donyavi et al. aimed to assess the retreatability of three endodontic sealers—AH 26, MTA Fillapex, and 5% fluoride varnish—using CBCT analysis. Forty-five extracted human mandibular premolars were instrumented, filled with gutta-percha and one of the three sealers, then subjected to retreatment after two months. The residual sealer volume was measured using MATLAB-assisted CBCT image analysis. Results showed AH 26 left significantly more residue in canals compared to MTA Fillapex and fluoride varnish. Notably, fluoride varnish and MTA Fillapex exhibited similar and significantly better retrievability.

8. An in-vitro study by Shivanand et al. compared the effectiveness of ProTaper Universal retreatment files, ProFile system, and traditional H-files in removing gutta-percha during endodontic retreatment. Sixty extracted premolars were assessed for cleaning ability, time to reach working length, and complete gutta-percha removal was done with help of solvent and assessed using CLSM. All systems proved effective, but none achieved completely clean canal walls. ProTaper Universal files were significantly faster and more efficient than both ProFile and H-files, especially in the coronal and middle thirds. The apical third consistently retained more debris across all groups. No apical extrusion or instrument separation was observed, and rotary systems showed better performance due to their design and cutting action. The study highlights that while rotary systems are more efficient than hand files, complete cleanliness remains a challenge.

9. An ex vivo study by Pawar et al. compared the effectiveness of the Self-Adjusting File (SAF) and WaveOne systems in removing residual root filling material from oval canals after initial retreatment with ProTaper files. Forty extracted maxillary canines were prepared and obturated using AH plus sealer following standard protocols. Following ProTaper retreatment with solvent, samples were divided into two groups: one using SAF and the other WaveOne. Cone-beam computed tomography (CBCT) was employed to measure remaining filling material. Results showed that canals treated with SAF retained significantly less residue (2.6 mm^3) than those treated with WaveOne (9.4 mm^3) ($p < 0.001$). Although both systems failed to completely clean the canals, SAF demonstrated superior cleaning efficacy in oval canals due to its adaptive design and continuous irrigation.

10. An in-vitro study by leu W et al. evaluates the physicochemical properties of GuttaFlow Bioseal, a novel bioceramic silicone-based root canal sealer. The investigation covered film thickness, flow, working/setting time, and thermal behavior using differential scanning calorimetry (DSC). Bioseal exhibited the highest film thickness (44 µm) and the lowest flow (21.43 mm), suggesting reduced penetration into fine anatomical spaces. It also had the shortest working (4.5 min at 37°C) and setting time (16.3 min), which may challenge practitioners with limited operating time. DSC results revealed Bioseal had the fastest and most intense exothermic reaction, peaking at 14 minutes, attributed to its dual setting mechanism (hydration and polymerization). In contrast, iRoot SP and AH Plus showed significantly longer setting times. These findings suggest that while Bioseal sets rapidly and efficiently, its handling and application require precision, making it suitable for experienced clinicians seeking time-efficient obturation in endodontic procedures.

11. An in-vitro study by Farrayeh et al. evaluated the effectiveness of two rotary retreatment systems—D-Race and ProTaper Universal Retreatment—with and without the supplementary use of XP–Endo Finisher R in removing calcium silicate-based sealers from root canals. Sixty single-rooted premolars were obturated using Ceraseal and gutta-percha, then retreated using four protocols. CBCT, digital microscopy, and SEM were used to analyze remaining materials. The study concluded that neither D-Race nor ProTaper alone could fully remove sealer residues. However, incorporating XP–Endo Finisher R significantly improved cleaning efficacy in both systems ($p < 0.05$). SEM imaging confirmed persistent calcium silicate residues in dentinal tubules despite EDTA and NaOCl irrigation. The study highlights the challenge of retreating bioceramic sealers due to their deep penetration and mineralization, emphasizing the need for supplementary mechanical activation.

12. An in-vitro study study by Kanchan Bhagat et al compared two root canal obturation techniques—Cold Lateral Compaction (CLC) and Warm Vertical Compaction (WVC) using the Continuous Wave of Compaction (CWC) technique—in simulated 30° curved canals made of transparent acrylic blocks (n=30) using weight-based assessment of gutta-percha fill.The mean weight of gutta-percha used was significantly higher in the WVC group (0.056 g) than in the CLC group (0.042 g) indicating better canal filling by weight in the WVC group.

13. An in-vitro study by Rafael Verardino de Camargo et al. to assess the physicochemical properties of AH Plus, GuttaFlow 2, GuttaFlow BioSeal, and MM Seal, five samples of each root canal sealer were evaluated to determine their setting time (ST), dimensional change (DC), solubility (SL), flow (FL), and radiopacity (RD) according to American National Standards Institute/American Dental Association (ANSI/ADA) Specification 57. AH Plus showed the best dimensional stability and

lowest solubility, fully meeting ANSI/ADA standards. GuttaFlow 2 had the highest shrinkage and solubility, while MM Seal demonstrated the highest flow.

14. An in-vitro study by Zahra Sadat Madani et al. compared the effectiveness of D-RaCe, ProTaper Universal retreatment files, and hand H-files for the removal of obturation material from curved root canals.Tooth were obturated with standard GP cones using AH Plus sealer by cold lateral compaction method. CBCT imaging was used to assess residual obturation material. The duration of the procedure (including the required time for reaching working length [T1] and total working time [TT]) and procedural errors were also recorded. No significant differences were found in the amount of residual material among the groups. All three techniques were similarly effective in removing obturation material, though rotary instruments had higher fracture risk.

15. An in-vitro study by Kiran Rehman et al. to compare the effectiveness of orange oil and chloroform in gutta-percha removal during endodontic retreatment. Standard gutta-percha cones were used along with a calcium hydroxide-based sealer, and obturation was performed using the cold lateral compaction technique. For retreatment, a mechanical approach involving manual stainless steel hand files and Gates Glidden drills (#1–3) was employed. Both the Solvents were applied at the canal orifice, with additional drops used as needed. Postoperative periapical radiographs were used to evaluate the amount of residual gutta-percha. The study found no statistically significant difference in effectiveness between orange oil and chloroform, supporting orange oil as a safer alternative.

16. An in-vitro study by Hemant Kumar Yadav et al. compared the dissolution efficiency of xylene, eucalyptus oil, orange oil, and distilled water on three endodontic sealers: Adseal (epoxy resin-based), Apexit Plus (calcium hydroxide-based), and Endomethasone N (zinc oxide-eugenol-based). 240 sealer samples were immersed in each solvent for 2 and 10 minutes, with percentage weight loss measured to evaluate dissolution. Xylene was the most effective solvent, especially after 10 minutes, while eucalyptus oil and orange oil performed similarly and were moderately effective, particularly on Apexit Plus and Endomethasone N. Adseal showed the least solubility. No mechanical instrumentation was used in the study, and files were not applicable.

17. An in-vitro study by Germain Sfeir et al. reviewed the clinical performance of calcium silicate-based sealers, highlighting their superior biological behavior compared to traditional sealers, with advantages in biocompatibility, antimicrobial effects, and bioactivity. However, they noted concerns regarding higher solubility and formulation variability. While these sealers show promise, further research is needed on their long-term performance, retreatability, and formulation differences to establish more standardized guidelines for their use in endodontics.

18. An in-vitro study by Flora Kakoura et al. conducted a comprehensive literature review on the retreatability of new-generation obturating materials, focusing on bioceramic sealers such as BioRoot RCS and iROOT SP. The review highlighted that while these sealers often left significant remnants on root canal walls, the re-establishment of working length and patency during retreatment was achievable and comparable to traditional sealers. This suggests that bioceramic sealers can be retreated effectively, although complete removal may be challenging. The study

emphasizes the need for further research to optimize retreatment protocols and improve the removal efficiency of these materials.

19. An in-vitro study by Mai H. Abdelrahman et al. conducted an in in-vitro study to compare the cleanliness of root canals treated with ADSEAL (epoxy resin-based), Well-Root ST, and CeraSeal (calcium silicate-based). ProTaper Retreatment Universal files were used to remove the obturation material. The canals were filled with gutta-percha and the respective sealers. After retreatment, the root canal walls were examined under a scanning electron microscope (SEM) at 1000× magnification to assess the cleanliness by observing the number of open dentinal tubules. The results showed ADSEAL left the most open dentinal tubules, indicating better cleanliness and retrievability, while Well-Root ST and CeraSeal left more residual material

20. An in-vitro study by S. López-García et.al, investigated the biological properties of three calcium silicate-based sealers: EndoSequence BC Sealer, Ceraseal, and Endoseal MTA. Their findings revealed that Ceraseal and EndoSequence BC Sealer exhibited enhanced ion release, improved cell adhesion, and greater mineralization potential when compared to Endoseal MTA, indicating superior biological performance.

MATERIALS AND METHODS

Study design

In-vitro study.

Source of data

The study was conducted in Department of Conservative Dentistry and Endodontics, KLE VK Institute of Dental Sciences Belagavi, KAHER.

Extracted human mandibular premolar teeth was collected from the Department of Oral and Maxillofacial surgery, KLE VK Institute of Dental Sciences Belagavi, KAHER.

Specimens were evaluated under Cone Beam Computed Tomography (CBCT) at The Department of Oral Medicine and Radiology, KLE VK Institute of Dental Sciences Belagavi, KAHER.

Inclusion criteria

Human permanent mandibular premolar teeth with single straight canal with closed apex.

Exclusion criteria

Teeth with calcified canals.

Teeth with fracture or crack

Teeth with the presence of anatomic variations/multiple canals

Teeth with curvature

Teeth with apical width more than #25 k.

Materials used for the study:

1. Extracted human permanent mandibular premolar teeth
2. 0.1% Thymol (S D FINE-CHEMICALS LIMITED, MUMBAI)
3. 3% Sodium Hypochlorite (NaOCl) (VISHAL DENTOCARE, AHMEDABAD, GUJRAT)
4. 17% Ethylenediaminetetraacetic Acid (EDTA) [GLIDE]
5. Normal saline solution (AMANTA HEALTHCARE, AHMEDABAD, GUJRAT)
6. Paper points (DIADENT GROUP INTERNATIONAL, KOREA)
7. AH Plus sealer (DENTSPLY)
8. GuttaFlow Bioseal sealer (COLTENE WHALEDENT, SWITZERLAND)
9. Ceraseal sealer (METABIOMED CO., KOREA)
10. Thermoplasticized gutta-percha cartriges (DENTSPLY SIRONA, USA)
11. Cavit (3M, ESPE, USA)

ARMAMENTARIUM USED FOR THE STUDY

1. Airotor (NSK, JAPAN)
2. Endomotor (EIGHTEETH®, ORIKAM HEALTHCARE, CHINA)
3. K Files (10-30) (MANI INC, JAPAN)
4. Protaper universal rotary files (DENTSPLY MAILLEFER, SWITZERLAND)
5. ProTaper Universal Retreatment files (DENTSPLY MAILLEFER, SWITZERLAND)
6. Hand plugger (MANI)
7. 5ml 27 gauge syringe (DISPOVAN, INDIA)
8. Gutta-Smart cordless obturation system (DENTSPLY SIRONA, USA)
9. Ultrasonic unit (WOODPECKER, GUANGZHOU, CHINA)

10. Lentulospirals (MANI, JAPAN)
11. Diamond disks (KWALITY DIAMOND TOOLS, MUMBAI)
12. Incubator (BIO TECHNICS, MUMBAI, INDIA)
13. Dental operating microscope (CARL ZEISS AG)
14. CBCT (DENTSPLY SIRONA)

SAMPLE SIZE ESTIMATION:

At 95%- Confidence Interval

95%- Power

$$n = \frac{(Z1 - \alpha/2 + Z1 - \beta)^2 (SD_1{}^2 + SD_2{}^2)}{(\overline{x}1 - \overline{x}2)2}$$

SD1 = 11.86

SD2 = 1.33

x̄1 = 15.64

x̄2 = 1.61

Z1-α/2 = 1.96

Z1-β = 1.64

Estimated sample size for each group, n = 15

Total sample size= 45

METHODOLOGY

Forty five extracted human mandibular premolar single rooted teeth were selected and handled according to OSHA guidelines. The teeth were decoronated using a diamond disc under copious water spray to acquire a standardized root length of 14 mm from the apex. Working length was established 1mm short of the root length till 10K file exits the apical foramen. Cleaning and shaping was performed using Protaper Universal Rotary system till MAF F3. 2ml of 3% of Sodium hypochlorite was used as an irrigant, after each change of instrument. Final rinse was done by 17% ethylenediaminetetraacetic acid (EDTA) followed by saline. The root canals were dried by using paper points. Then, the samples were randomly divided into 3 groups based on the sealer used (n=15).

Group I: Epoxy resin-based sealer + Thermoplasticized gutta-percha

Group II: Silicone-based sealer +Thermoplasticized gutta-percha

Group III: Calcium silicate-based sealer +Thermoplasticized gutta-percha.

The sealers were mixed according to the manufacturer's instructions and were coated on the canal walls, 1mm short of the apex using a No. 25 lentulospiral. Obturation was done using Continous Wave Compaction technique. Post obturation CBCT images were taken to check the quality of obturation. Samples with voids or incomplete obturation were discarded from the study and a new sample was added to the group. Teeth were sealed with Cavit and incubated at 37°C and 100% humidified conditions for 2 weeks. After 2 weeks, Cavit was removed with round bur, thus forming a reservoir for the solvent. Drop of Orange oil (GP solvent) was applied to the gutta-percha for 2-3 mins and a size 25 K file was used to establish a glide path before introducing rotary instruments. All the samples were retreated using Potaper

Universal Retreatment system. The D1, D2 and D3 files were sequentially used at a speed of 500rpm. The retreatment files were utilized for a maximum of three canals. Each file was examined under magnification for any signs of distortion or fracture following use. Files exhibiting any visible deformation or structural compromise were immediately discarded to ensure standardization and procedural safety At each change of instrument, the root canals were irrigated with 2ml of 3% Sodium hypochlorite. When the instrument reaches apical one-third use of solvent was discontinued. The working length was maintained and root canals were reshaped using Protaper Universal rotary system to a MAF size F3. At the end of this procedure, all root canals were irrigated with 2ml of 3% Sodium hypochlorite, 17% EDTA, followed by final flush of saline and was dried with paper points. Retreatment time for complete removal of obturating material was recorded using stopwatch. The samples were evaluated using CBCT in axial , coronal and sagittal sections for remanants of gutta-percha and sealer.

CBCT cross-sections was analysed and scores will be obtained for all the CBCT images by using formula: (S1/S2)X100

S1 is the surface area of the residual obturating material

S2 is the surface area of the root canal.

MATERIALS USED FOR THE STUDY:

Fig. 1 Total Sample size (n=45)

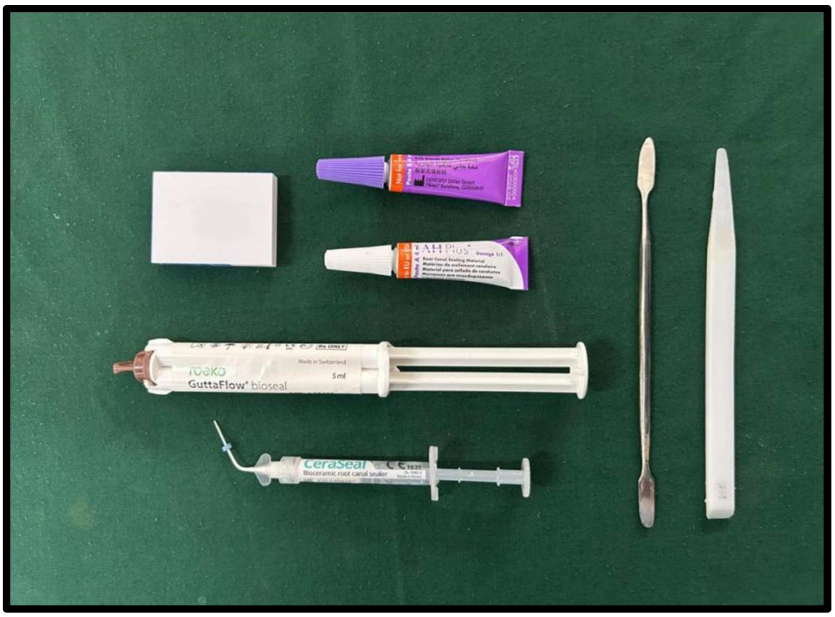


Fig. 2 Tested Materials-Root canal sealers

Fig. 3 Materials

Fig. 4 Armamentarium

Fig. 5 Debris Removal

Fig. 6 Sample decoronated at the level of CEJ using Diamond disc

Fig. 7 Study done under dental microscope

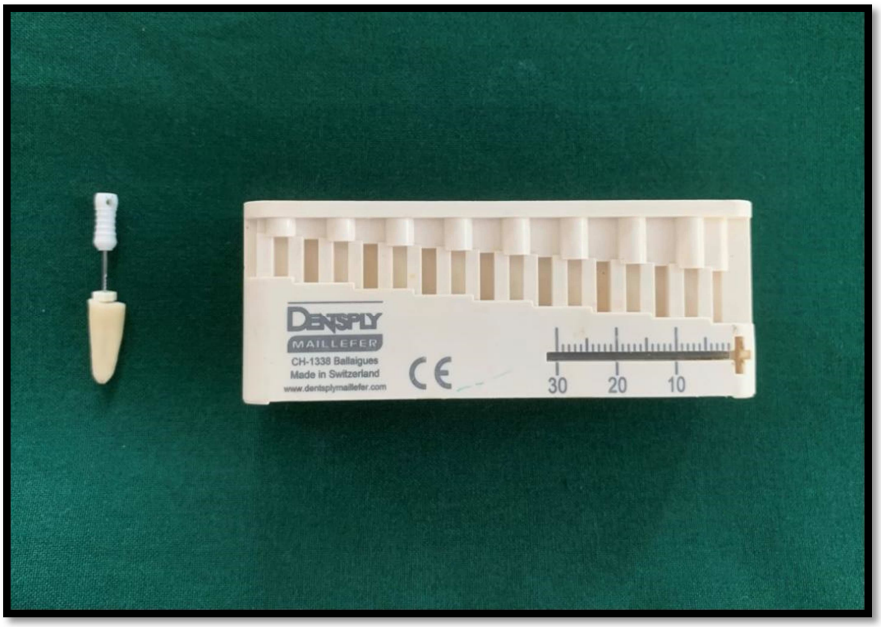


Fig. 8 Working length determination

Fig.9 Bio-mechanical Preparation

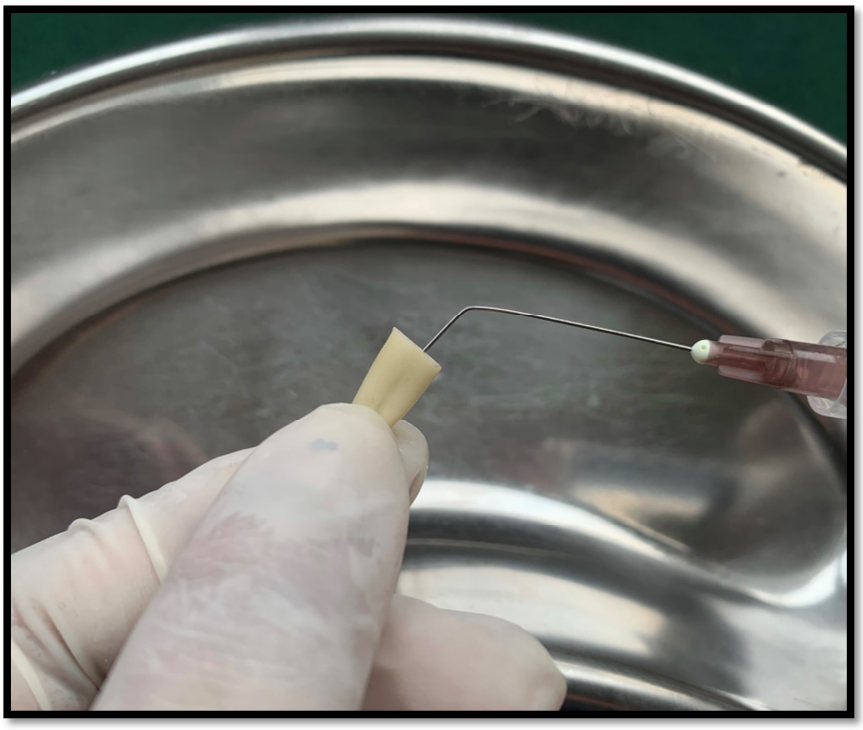


Fig.10 Sodium Hypochlorite Irrigation In between Instrumentation and final irrigation by 17 % EDTA, followed by saline

Fig.11 Drying canals with paper points

Fig.12 Sealer placement using lentulospiral no. 25

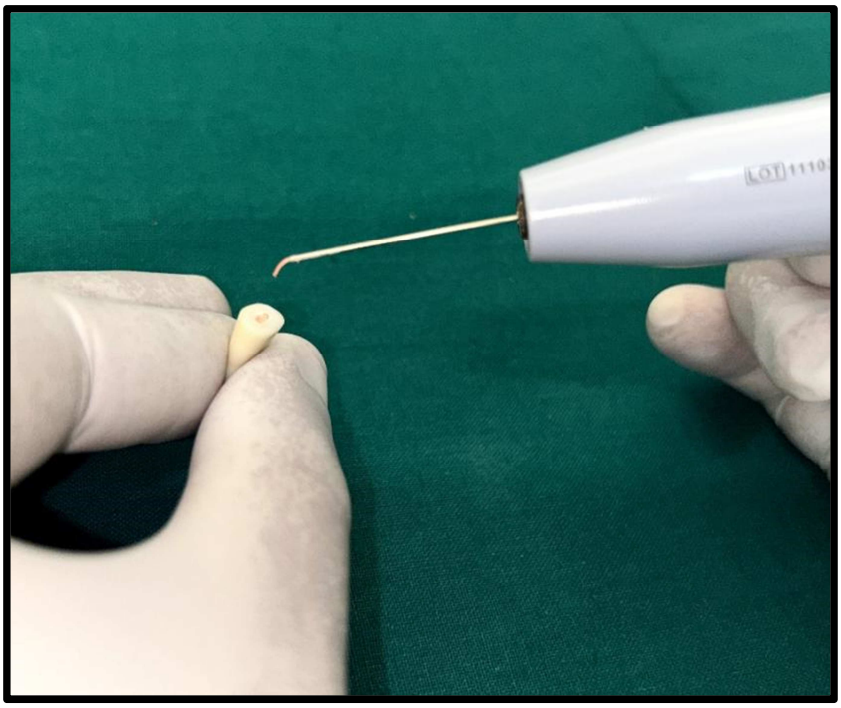


Fig. 13 Obturation done Continuous wave compaction (Backfill unit)

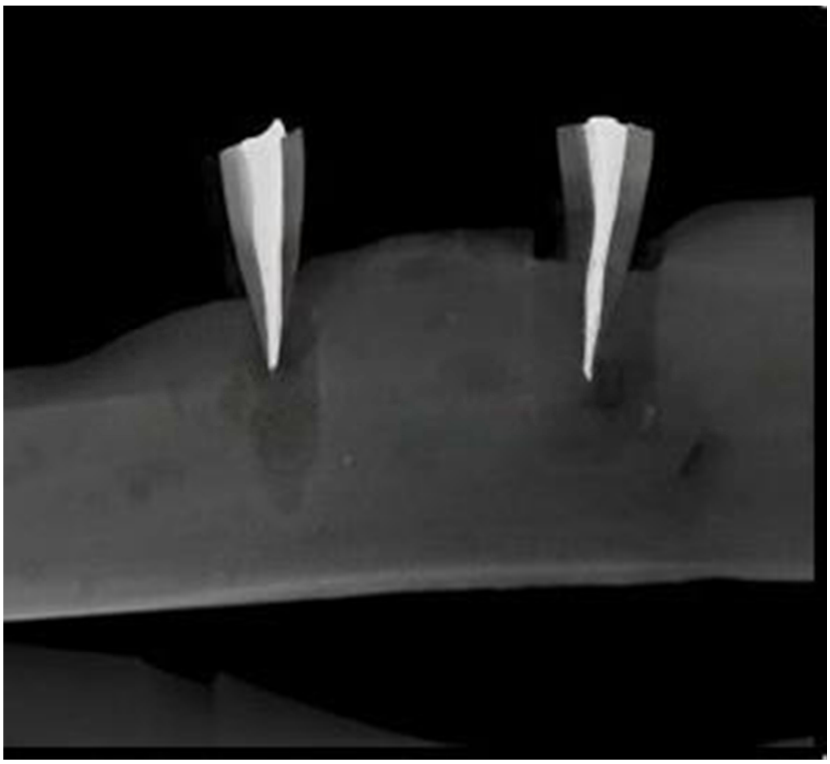


Fig.14 Post obturation CBCT image

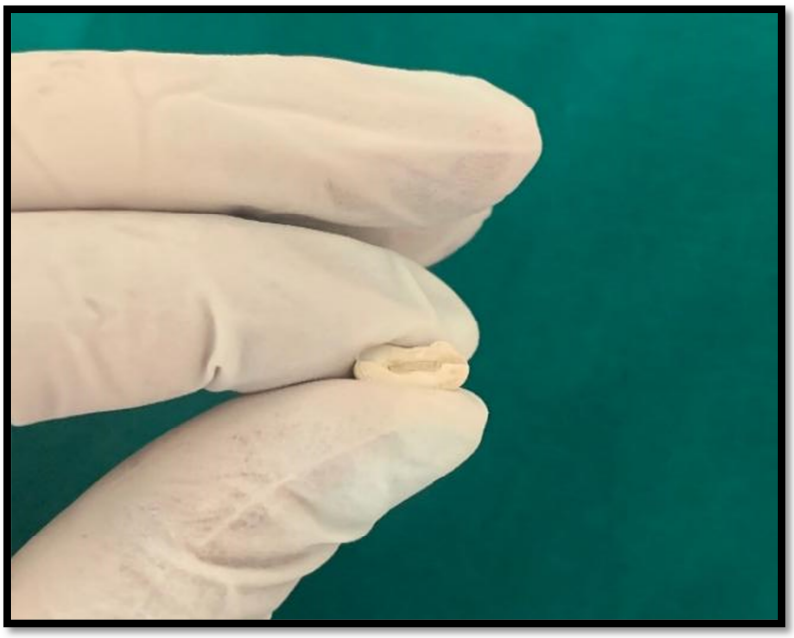


Fig.15 Access sealed with temporary filling material (Cavit)

Fig.16 Incubation

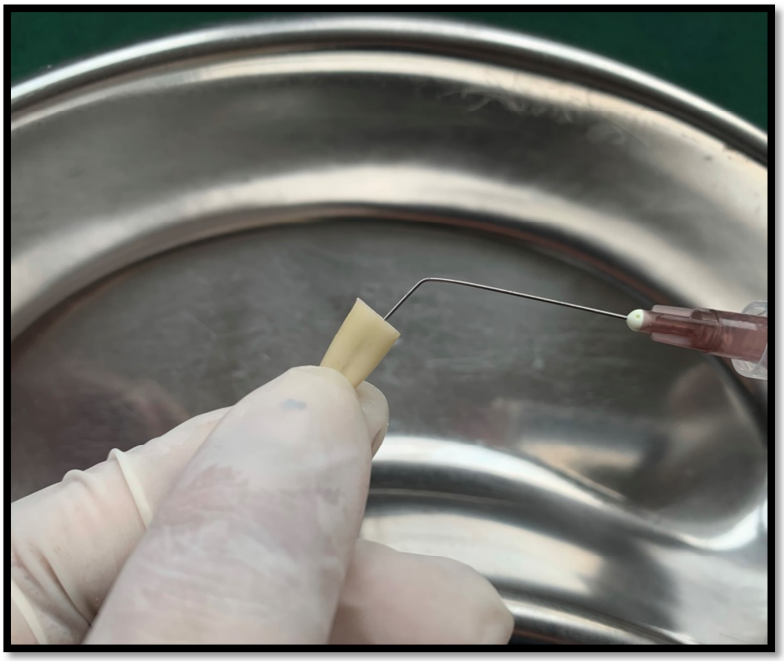


Fig.17 Solvent applied on the gutta-percha

Fig.18 Obturating material removed using Protaper Universal Retreatment system

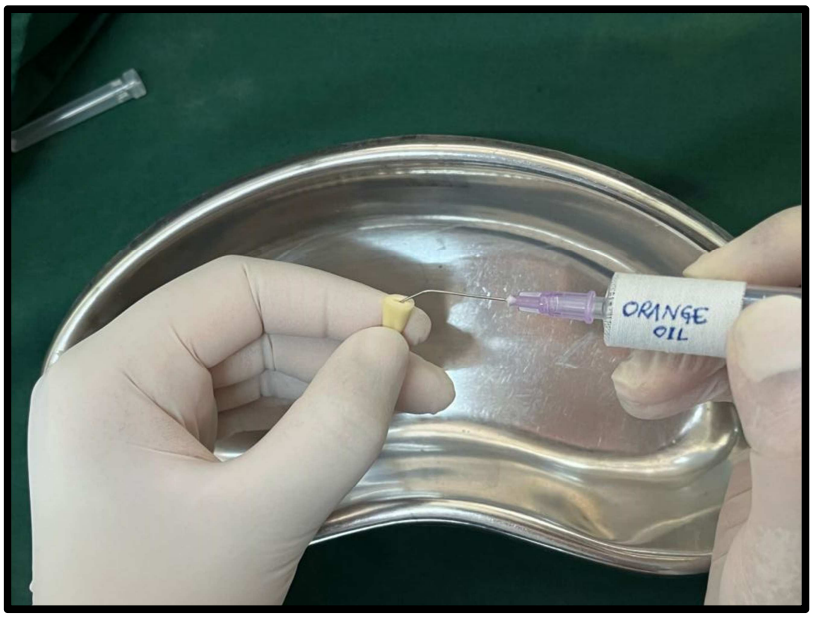


Fig.19 3% Sodium hypochlorite used between instrumentation

Fig.20 Root canals were reshaped using Protaper Universal rotary system

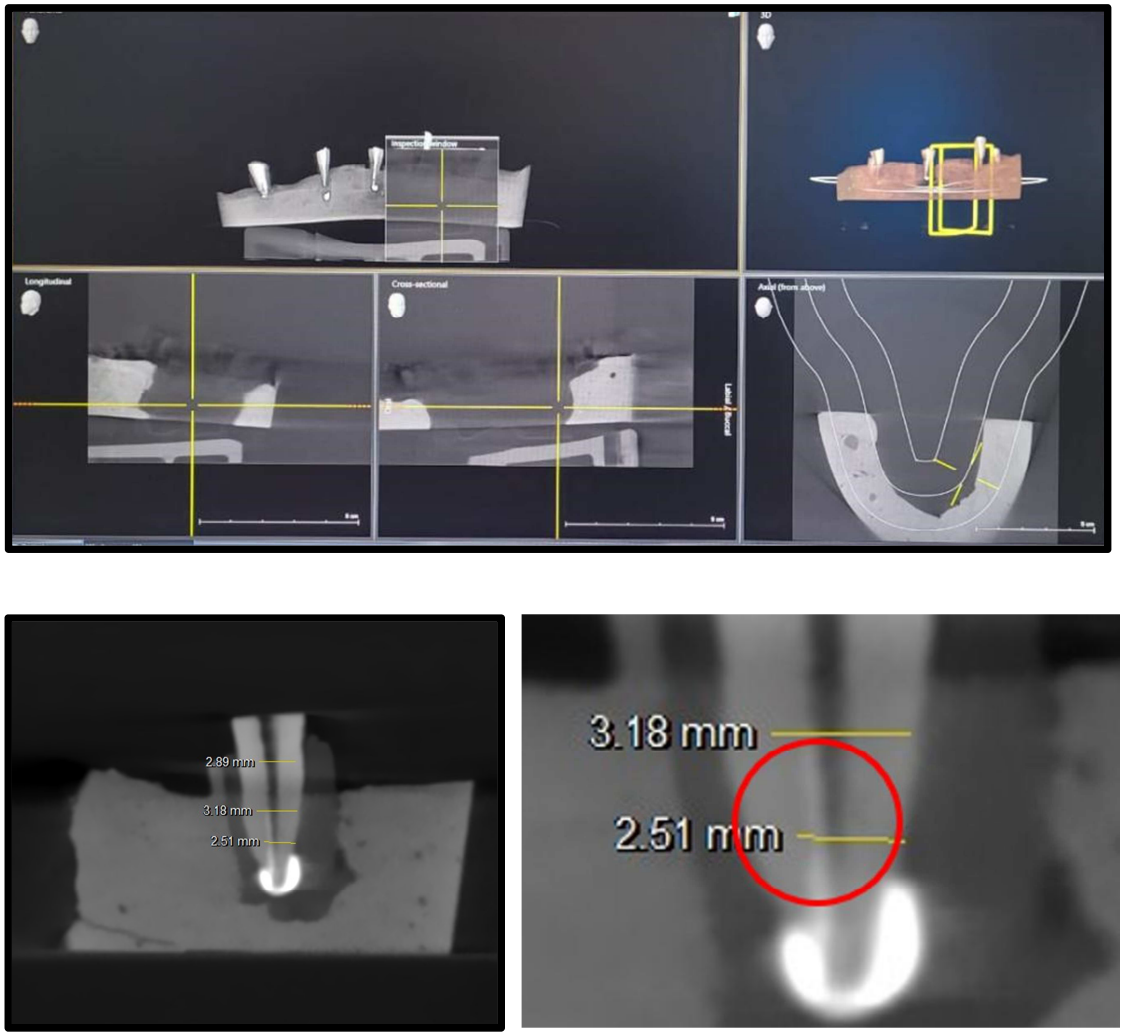


Fig.21 CBCT evaluation

RESULTS

Table 1: Summary of surface area of obturating material in three groups and three thirds

Factor	Levels	n	Mean	Std.Dev.	Std.Err	95% CI for mean	
						Lower	Upper
Group	AH Plus	45	2.45	1.20	0.18	1.24	2.81
	GuttaFlow	45	1.49	0.82	0.12	2.09	1.74
	Ceraseal	45	3.07	1.34	0.20	2.67	3.48
Third	Apical third	45	3.04	1.37	0.20	2.63	3.45
	Middle third	45	2.22	1.19	0.18	1.87	2.58
	Coronal third	45	1.75	1.03	0.15	1.44	2.06
Interaction	AH Plus with Apical third	15	3.23	1.21	0.31	2.56	3.90
	AH Plus with Middle third	15	2.24	1.02	0.26	1.68	2.80
	AH Plus with Coronal third	15	1.88	1.01	0.26	1.33	2.44
	GuttaFlow with Apical third	15	2.03	0.73	0.19	1.63	2.42
	GuttaFlow with Middle third	15	1.39	0.74	0.19	0.98	1.80
	GuttaFlow with Coronal third	15	1.05	0.72	0.19	0.65	1.46
	Ceraseal with Apical third	15	3.87	1.43	0.37	3.08	4.66
	Ceraseal with Middle third	15	3.04	1.17	0.30	2.39	3.69
	Ceraseal with Coronal third	15	2.31	0.96	0.25	1.78	2.84

Table 1 depicts structured summary of the surface area of obturating material in the three sealer groups (AH Plus, GuttaFlow, and Ceraseal) across the three canal thirds (apical, middle, and coronal):

Overall Interpretation- Table 1 depicts a statistical analysis revealed significant differences in the residual surface area of obturating materials across sealers and root canal thirds following retreatment. The mean surface area of remaining filling material was highest in the apical third and lowest in the coronal third**,** indicating increasing difficulty in material removal as one progresses apically. Among the three sealers tested—Group I- Epoxy resin based sealer **(**AH Plus**),** Group II- Silicone based sealer (GuttaFlow Bioseal**),** and Group III- Calcium silicate based sealer **(**Ceraseal)**—**Group III, showed the highest overall mean residual surface area, suggesting its lower retreatability, while Group II, demonstrated the **l**east amount of residual material**,** indicating better removal efficiency**.**

Group-wise Comparison-

- Group I- Epoxy resin based sealer, demonstrated the moderate residual values compared to the other groups. The highest residual surface area was found in the apical third ($3.23 \pm 1.21\ mm^2$), followed by the middle ($2.24 \pm 1.02\ mm^2$), and coronal third ($1.88 \pm 1.01\ mm^2$). While not as difficult to remove as Group III, AH Plus still left a significant amount of residue, particularly in the apical region.

- Group II- Silicone based sealer, demonstrated the lowest mean residual values in all three thirds, indicating superior retreatability**.** The apical third retained $2.03 \pm 0.73\ mm^2$, the middle third $1.39 \pm 0.74\ mm^2$, and the coronal third only $1.05 \pm 0.72\ mm^2$. These results suggest that Group II is the most easily retrievable sealer.

- Group III- Calcium silicate based sealer exhibited the greatest amount of residual obturating material across all three canal thirds. The apical third showed the highest mean value ($3.87 \pm 1.43\ mm^2$), followed by the middle third ($3.04 \pm 1.17\ mm^2$), and the coronal third ($2.31 \pm 0.96\ mm^2$). These findings suggest that Group III is more resistant to removal**,** particularly in the apical region.

Table 2: Comparison of three groups and three thirds with surface area of obturating material by Two way ANOVA

Sources of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F-value	p-value
Main effects					
Groups	57.3400	2	28.6700	27.2900	0.0001*
Thirds	38.4856	2	19.2428	18.3166	0.0001*
2-way interaction effects					
Group*Third	1.6711	4	0.4178	0.3977	0.8100
Error	132.3716	126	1.0506		
Total	229.8683	134			

*$p<0.05$

Table 2. depicts the results of a two-way ANOVA analysis, which evaluates the effects of sealer group and canal third on the surface area of obturating material remaining after retreatment. The statistical analysis using two-way ANOVA revealed that both the type of sealer used (Groups) and the root canal region (Thirds: coronal, middle, apical) had a statistically significant effect on the residual surface area of obturating materials left after retreatment **(**$p = 0.0001$***** for both factors). The F-value for sealer groups was 27.29**,** and for canal thirds, it was 18.31**,** indicating strong statistical significance and influence on the outcome. However, the interaction

between the type of sealer and canal third (Group × Third) **was** not statistically significant **(**p = 0.8100**),** suggesting that the effect of each sealer on residual material was consistent across all canal regions**.** This means while the type of sealer and the canal third independently affect retreatability, they do not influence each other's effect.

Table 3: Pair wise comparison of three groups with surface area of obturating material by Tukey's multiple posthoc procedures

Groups	AH Plus	GuttaFlow	Ceraseal
Mean	2.45	1.49	3.07
Std.Dev.	1.20	0.82	1.34
AH Plus		-	
GuttaFlow	-	P=0.0001*	
Ceraseal	P=0.0001*	P=0.0112*	-

*p<0.05

Table 3. depicts Pair wise comparison of the three groups with surface area of obturating material by Tukey's multiple posthoc procedures

Group with Highest Resistance: Group III- Calcium silicate based sealer, demonstrated the highest residual surface area **(**3.07 mm^2**),** making it the most difficult sealer to remove during retreatment.

Group with Moderate Resistance: Group I- Epoxy resin based sealer, showed a moderate residual surface area **(**2.45 mm^2**),** indicating it is moderately difficult to

remove. Its epoxy resin-based composition allows for easier retreatment compared to bioactive sealers but is still harder to remove than Group II.

Group with Lowest Resistance: Group II- Silicone based sealer, showed **the** lowest residual material **(**1.49 mm²**),** making it the easiest sealer to remove.Its silicone-based composition and weaker adhesion to dentin contribute to its greater retreatability.

Table 4: Pair wise comparison of three thirds with surface area of obturating material by Tukey's multiple posthoc procedures

Thrid	Apical third	Middle third	Coronal third
Mean	3.04	2.22	1.75
Std.Dev.	1.37	1.19	1.03
Apical third	P=0.0001*		-
Middle third	P=0.0731	-	
Coronal third	-	P=0.0005*	

*p<0.05

Table 4. depicts the results of Tukey's multiple post-hoc test**,** which compares the surface area of residual obturating material across the three canal thirds (apical, middle, and coronal) after retreatment.

The quantitative evaluation of the residual obturating material across different thirds of the root canal revealed distinct variations in surface area distribution. Statistical analysis using Tukey’s multiple post-hoc test demonstrated that the apical third retained the highest amount of obturating material (mean = 3.04 ± 1.37), followed by the middle third (mean = 2.22 ± 1.19), while the coronal third exhibited the least residual material (mean = 1.75 ± 1.03). A statistically significant difference was

observed between the apical and coronal thirds (p = 0.0001*) and between the middle and coronal thirds (p = 0.0005*), indicating a progressive reduction in residual material from apical to coronal regions. Although the comparison between the apical and middle thirds did not reach statistical significance (p = 0.0731), the data suggest a clear trend of increased difficulty in obturating material removal in the apical third of the root canal system. This finding underscores the anatomical complexity and limited accessibility of the apical third, which may impede effective cleaning and retreatment procedures.

Table 5: Pair wise comparison of interactions of three groups and three thirds with surface area of obturating material by Tuekys multiple posthoc procedures

Interaction	GuttaFlow with Coronal third	GuttaFlow with Middle third	GuttaFlow with Apical third	AH Plus with Coronal third	AH Plus with Middle third	AH Plus with Apical third	Ceraseal with Coronal third	Ceraseal with Middle third	Ceraseal with Apical third
Mean	2.03	1.39	1.05	3.23	2.24	1.88	2.31	3.04	3.87
SD	0.72	0.74	0.73	1.21	1.02	1.01	1.43	1.17	0.96
GuttaFlow with Coronal third	-								
GuttaFlow with Middle third	p=0.9935	-							
GuttaFlow with Apical third	p=0.1861	p=0.7406	-						
AH Plus with Coronal third	p=0.3928	p=0.9229	p=0.9999	-					
AH Plus with Middle third	p=0.0402*	p=0.3520	p=0.9997	p=0.9897	-				
AH Plus with Apical third	p=0.0001*	p=0.0001*	p=0.0358*	p=0.0099*	p=0.1709	-			
Ceraseal with Coronal third	p=0.0222*	p=0.2472	p=0.9979	p=0.9681	p=0.9999	p=0.2555	-		
Ceraseal with Middle third	p=0.0001*	p=0.0004*	p=0.1462	p=0.0525	p=0.4523	p=0.9999	p=0.5821	-	
Ceraseal with Apical third	p=0.0001*	p=0.0001*	p=0.0001*	p=0.0001*	p=0.0005*	p=0.7384	p=0.0010*	p=0.3916	-

*p<0.05

Table 5. depicts the pairwise comparison of interactions between the three sealers Group I- Epoxy resin based sealer **(**AH Plus), Group II- Silicone based sealer **(**GuttaFlow Bioseal), and Group III- Calcium silicate based sealer (Ceraseal**,** and also the three canal thirds (apical, middle, and coronal) in terms of the surface area of residual obturating material**.** The Tukey's multiple post-hoc test was applied to identify significant differences between the groups.

The results reveal that the type of sealer and the specific region of the root canal significantly influenced the amount of residual material after retreatment. Group III Calcium silicate based saeler consistently left the highest amount of obturating material in all three canal thirds, particularly in the apical third, suggesting its reduced retreatability. Group II- Epoxy resin based sealer, showed a moderate amount of residue, with more remaining in the apical third compared to the coronal, while Group II- Silicone-based sealer had the least residual material across all thirds, reflecting its better removal efficiency and retreatment-friendly nature.

Statistical analysis further confirmed that the apical third generally retained more material than the middle and coronal thirds, regardless of the sealer used. Moreover, significant differences were observed between most group combinations, except within Group III, canal thirds where the retreatability remained fairly consistent throughout.

Table 6: Summary of time taken for the complete removal of obturating material .

Group	N	Mean	SD	SE	95% CI for mean	
					Lower	Upper
AH plus	45	6.41	0.79	0.12	6.18	6.65
GuttaFlow Bioseal	45	2.63	0.91	0.14	2.36	2.91
Ceraseal	45	7.18	0.84	0.13	6.93	7.43

Table 6. depicts the time required for complete removal of different root canal sealers using the ProTaper Universal Retreatment system is summarized as follows:

- **Group II- Silicone-based sealer, d**emonstrated the shortest mean time for removal (2.63 minutes), indicating it is the most easily retrievable compared to Group I and III
- **Group I- Epoxy resin-based sealer, r**equired a moderate amount of time for removal (6.41 minutes), suggesting moderate retreatability when compared to Group II and III
- **Group III- Calcium silicate-based sealer, t**ook the longest time to remove (7.18 minutes), indicating it is the most challenging to retreat when compared to Group I and II

Table 7: Comparison of three groups mean time taken by one way ANOVA

Sources of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	p-value
Between groups	2	533.9224	266.9612	368.2854	0.0001*
Within groups	132	95.6836	0.7249		
Total	134	629.6060			

*p<0.05

This high F-value suggests that the variability between the group means is much greater than the variability within the groups. In other words, the type of sealer used has a significant effect on the time required for removal.

Since the p-value is less than the conventional alpha level of 0.05, we reject the null hypothesis that all group means are equal. This confirms that at least one group's mean removal time differs significantly from the others.

Table 8: Pair wise comparison of three groups mean time taken by Tukeys multiple posthoc procedures

Group	AH plus	GuttaFow	Ceraseal
Mean	6.4133	2.6311	7.1809
SD	0.7905	0.9145	0.8447
AH plus	-		
GuttaFow	P=0.0001*	-	
Ceraseal	P=0.0001*	P=0.0001*	-

*p<0.05

Table 8. depicts Pair wise comparison of three groups mean time taken by Tukeys multiple posthoc procedures.

Group I- Epoxy resin based sealer compared to Group II-Silicone based sealer required statisically moderate time for removal.

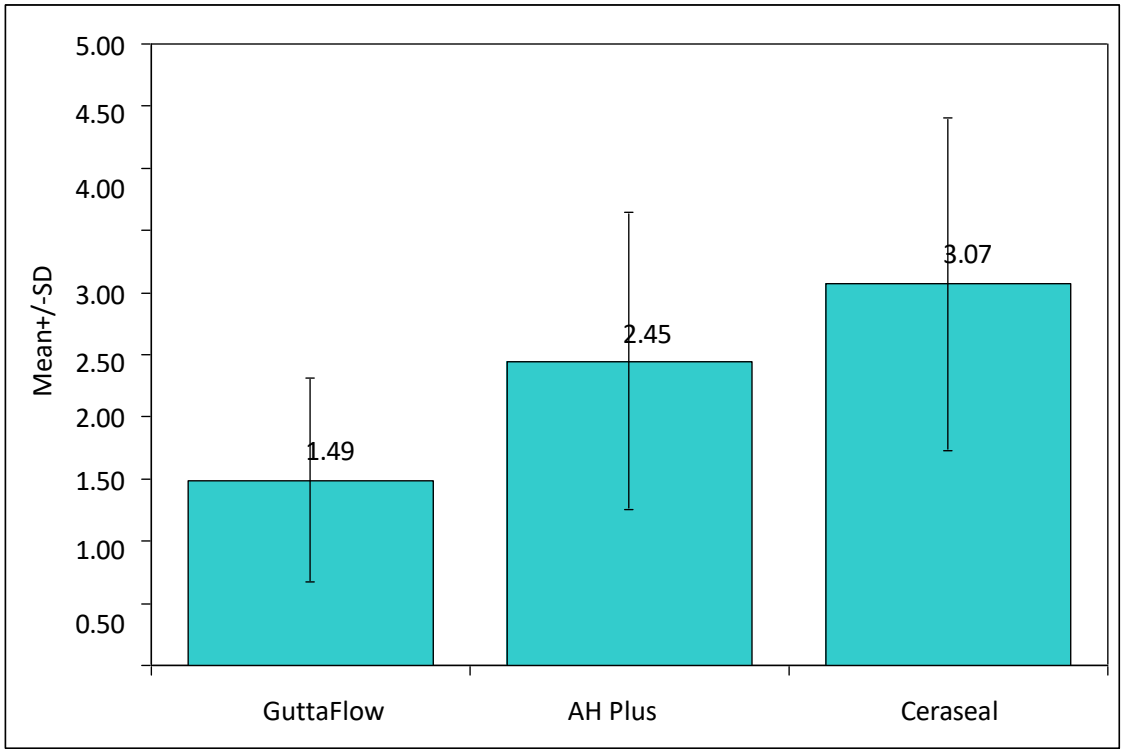
Group I- Epoxy resin based sealer compared to Group III- Calcium silicate based sealer required satistically moderate time for removal.

Group II-**Silicone based sealer compared to Group I-** Epoxy resin based sealer, required statistically less time for removal.

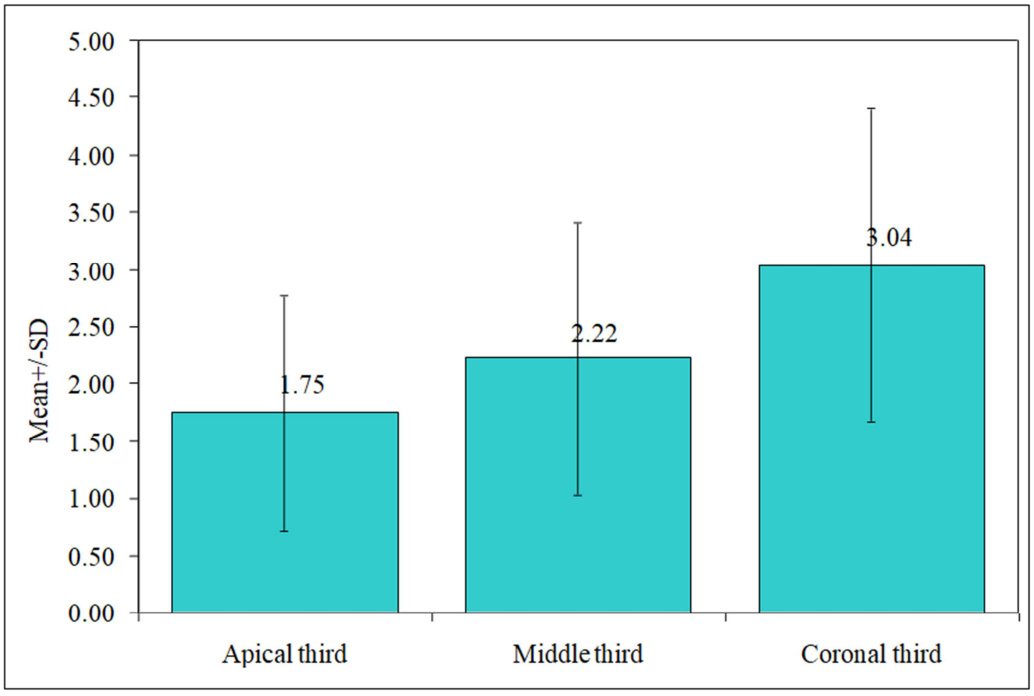
Group II-**Silicone based sealer compared to Group III-** Calcium silicate based sealer required statistically less time for removal.

Group III- Calcium silicate based sealer compared to **Group I-** Epoxy resin based sealer required statistically longest time for removal.

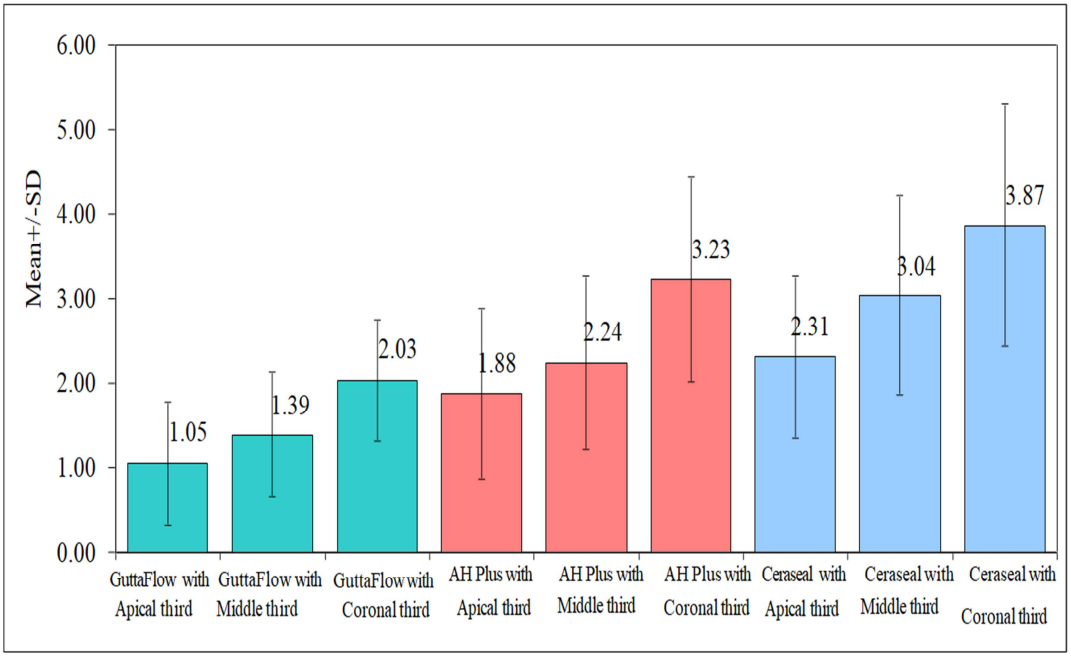
Graph 1: Pair wise comparison of three groups with surface area of obturating material



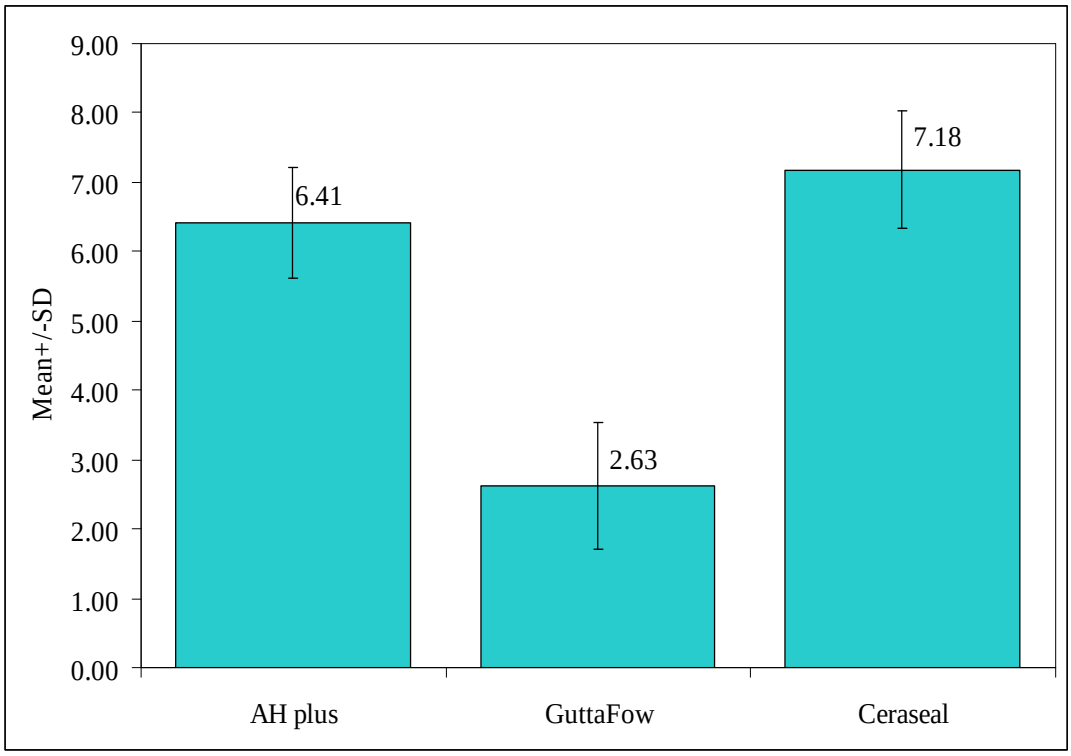
Graph 2: Pair wise comparison of three thirds with surface area of obturating material



Graph 3: Comparison of interactions of three groups and three thirds with surface area of obturating material



Graph 4: Comparison of three groups mean time taken



DISCUSSION

Root canal treatments usually fail due to persistent periapical disorders after treatment. According to Gabriel et al, Abou-Rass et al, the major cause of treatment failure is incomplete removal of microorganisms and bacterial biofilms, insufficient cleaning and inadequate filling.[1] In addition, these etiological factors should be eliminated to establish adequate periapical recovery; thus, establishing patency and working length in retreatment cases could significantly provide for better periapical healing outcomes. However, retreatment procedures are not always possible due to several factors, including root canal anatomy and resistant fillings materials [2]

Premolars were selected in this study because they are extracted commonly for orthodontic treatment. Canals are flattened mesiodistally, an important anatomic variation during their treatment. Decoronation assured standardization of the specimens. Premolars were prepared initially to size 25 with 2% taper K-file. This was assumed to represent, narrow and underprepared root canals. Such canals are frequently found in retreatment.[3]

In this study, dental operating microscope was used to simulate the clinical scenario during root canal retreatment. The use of dental operating microscope with its illumination and magnification during root canal retreatment reported to facilitate the detection of residual root filling materials, the cleanliness of the canal wall, and evaluation of the retreatment.[1]

The purpose of an endodontic sealer is to fill the gaps between the root canal wall and core material to reduce leakage from coronal as well as apical restoration and it also blocks the dentinal tubules. Grossman has quoted one of the basic requirement for an ideal root canal sealer is to be soluble in a solvent in case of retreatment. [4]

An Epoxy resin based-sealer was chosen in this study, as resin sealers are the most commonly used sealers these days due to their stability, biocompatibility, good handling properties and adequate adhesion to dentin.[5]

GuttaFlow Bioseal (Coltene Whaldent) is a novel bioceramic silicone-based sealer, contains bioceramic particles and gutta-percha powder in a silicone matrix. Studies have evaluated the bioactivity of GuttaFlow Bioseal and its insolubility to tissue fluids and more fluid tight seal, which represents an attractive strategy.[6]

Calcium silicate-based materials are increasingly utilized in endodontic practice due to their favorable biological, mechanical, and physicochemical characteristics. Ceraseal, a Calcium silicate-based sealer used in the present study, exhibits an alkaline pH and releases calcium ions (Ca^{2+}), which may facilitate mineralization and promote the formation of hydroxyapatite tags within dentinal tubules. In this study, Ceraseal was evaluated for its retreatability in comparison with two other commonly used sealers stated above, to date, limited literature exists regarding its removal efficiency, highlighting the relevance of this investigation. [7]

The role of a solvent is not only in dissolving the gutta-percha but also in lubrication of instruments, thus diminishing the possibility of instrument breakage, root perforation and canal straightening. In this study, Orange oil was used, which is proposed as an effective gutta-percha solvent at 37ºC. There is no evidence for its carcinogenicity or genotoxicity. Further, orange oil is less cytotoxic and more biocompatible than eucalyptol and chloroform. [3,8]

The ProTaper Universal Retreatment (PTR) system includes three instruments with various tapers and diameters at the tip (D1 30/0.09, D2 25/0.08 and D3 20/0.07). D1 has a cutting tip to facilitate initial penetration into filling materials. D2 and D3

both have non-cutting tips and are used to remove the obturating materials from the mid and apical thirds, respectively.[9]

In the present study, the ProTaper Universal NiTi retreatment system was used for the removal of root canal filling materials. This system has been shown to be more effective in thoroughly eliminating obturating materials compared to conventional retreatment techniques.[5]

Cold lateral condensation (LC) has long been the most commonly employed root canal obturation technique and is often considered the gold standard against which other methods are compared. However, studies have reported that this technique may result in voids within the filling, which can either remain unfilled or be occupied by sealer, potentially resorbing over time and compromising the seal.[10] In 1977, Yee et al. introduced an obturation technique involving thermoplasticized gutta-percha injection, which aimed to create a denser and more uniform three-dimensional filling. This method has demonstrated superior adaptation to the canal walls and replication of complex canal anatomy, offering a seal that is comparable or superior to conventional methods.[11] In the present study, the Continuous Wave Compaction technique was utilized, which is considered more effective than traditional techniques in achieving a dense, homogeneous fill and improved apical seal.[12]

In this study, a Epoxy resin-based root canal based-sealer, AH Plus, (Dentsply Konstanz, Germany); a Silicone-based root canal sealer, GuttaFlow Bioseal, (Coltene/Whaldent) and a Calcium silicate-based root canal sealer, Ceraseal (MetaBiomed, Korea) were used with Continous wave compaction (Thermoplasticized) obturation technique.[13]

Various methods have been utilized to assess the remnants of root canal sealers following retreatment procedures. Among these, Stereomicroscope, Micro-computed tomography (micro-CT), and cone-beam computed tomography (CBCT) are the most commonly employed. Stereomicroscope allows for direct visual evaluation of the canal surface; however, it requires sectioning of the tooth, which is a destructive process and may compromise the integrity of the sample. Micro-CT is considered the gold standard for three-dimensional assessment due to its high resolution and accuracy, yet its application is often limited by high costs, technical complexity, and limited accessibility in routine clinical practice.[14] In contrast, CBCT has gained popularity in recent years owing to its non-invasive nature, greater availability, and lower radiation exposure compared to conventional CT. CBCT exhibited better efficacy compared to routine radiographic techniques. It provides a 3D view of the root canal.[15]

Cone-beam computed tomography (CBCT) enables detailed visualization of internal morphological structures. It is a reliable, efficient, and sensitive tool capable of detecting even minimal remnants of root canal filling materials.[16] In the present study, CBCT was employed to provide reproducible data and to evaluate the efficacy of endodontic retreatment by assessing and comparing the quantity of obturating material within the root canals before and after the retreatment procedures. This facilitated a comprehensive analysis and accurate interpretation of the outcomes. [17]

For an effective endodontic therapy, it is crucial to effectively eliminate all the previously used root filling materials. Consequently, easy removal of sealers is one of its idealistic requirements if retreatment is mandatory to permit full accessibility for an antibacterial agent and medications to root canal ramifications.[5]

In the present in in-vitro study, CBCT investigations demonstrated that there was no retreatment system that could totally eliminate the remaining filling materials and completely open the dentinal tubules.[5] The present study evaluated the retreatability of three different root canal sealers—Epoxy resin based-sealer, AH Plus; Silicone based-sealer, GuttaFlow Bioseal, and Calcium silicate based-sealer, Ceraseal—by measuring the residual surface area of obturating material in the coronal, middle, and apical thirds of root canals following retreatment. Data were analyzed using two-way ANOVA and Tukey's multiple post hoc test to determine statistical significance between groups and canal thirds. A significance level of $p < 0.05$ was set for all comparisons

With respect to the results of our study, among the three sealers tested-— Group I-Epoxy resin based , Group II-Silicone based sealer , and Group III-Calcium silicate based-sealer. Group III- Calcium silicate sealer showed the highest overall mean residual obturating material, suggesting its lower retreatability when compared to Group I and II, while Group II- Silicone based sealer demonstrated the least amount of residual material, indicating better removal efficiency than Group I and III. Group I- Epoxy resin based sealer showed moderate amount of residual material.

Ceraseal exhibited the greatest amount of residual obturating material across all three canal thirds, making it the most difficult sealer to remove during retreatment. The apical third showed the highest mean value ($3.87 \pm 1.43\ mm^2$), followed by the middle third ($3.04 \pm 1.17\ mm^2$), and the coronal third ($2.31 \pm 0.96\ mm^2$). The bioactive properties and strong dentinal adhesion of Ceraseal likely contribute to this increased resistance to retreatment. Its ability to form hydroxyapatite crystals and interact chemically with dentin enhances its bonding strength, which in turn makes removal more challenging.

Obeid et al in 2015 , stated that the interaction of Calcium silicate based sealers with a phosphate containing fluid produces a structure that has the chemical and crystalline characteristics similar to that of both the tooth and the bone apatite. These apatites formed by deposits on the collagen fibrils, forming an interfacial layer with tag-like structures at the sealer-dentin interface. This phenomenon is claimed to enhance their bond strength to dentin. [18]

The statistically significant difference between Group III Calcium silicate based sealer when compared to Group I-Epoxy resin based sealer and Group II-Silicone based sealer ($p < 0.05$) further confirms its superior resistance to retreatment. These findings align with previous studies. Antoun Farrayeh et al. reported that calcium silicate-based sealers and cements are particularly challenging to remove during retreatment due to their high compressive strength, strong interaction with dental tissues, and their capacity to promote mineralization[15]

Also, Obeid *et al* in 2015 , stated that the interaction of Calcium silicate based sealers with a phosphate-containing fluid produces a structure that has the chemical and crystalline characteristics similar to that of both the tooth and the bone apatite. These apatites formed by deposits on the collagen fibrils, forming an interfacial layer with tag-like structures at the sealer-dentin interface. This phenomenon is claimed to enhance their bond strength to dentin.[5,19] This also explain the results of the our study, as to why Group III was difficult to retreat .

Group I- Epoxy resin based sealer, exhibited moderate resistance, with a mean residual surface area of 2.45 ± 1.20 mm². While this was significantly lower than Group III- Calcium silicate based sealer ($p < 0.05$), it was still higher than Group II-Silicone based sealer, indicating moderate difficulty in removal. The Epoxy resin-

based composition of AH Plus contributes to its strong dentinal adhesion, making it more resistant to removal than silicone-based sealers. However, compared to bioactive sealers like Ceraseal, its lower bonding strength and limited dentinal penetration make it relatively easier to retrieve.

Group I- Epoxy resin based sealer, had the highest residual surface area was found in the apical third ($3.23 \pm 1.21\ mm^2$), followed by the middle ($2.24 \pm 1.02\ mm^2$), and coronal third ($1.88 \pm 1.01\ mm^2$). The results align with the study by Donoso M et al. concluding, that AH Plus forms chemical bond with dentin by formation of covalent bond between epoxy group of resin and collagen amine group of dentin making it somewhat difficult to retreat.[20]

Also, Neto et al., has highlighted that the low polymerization stress of the sealer and its long-term dimensional stability may be the cause of the high bond strength of AH Plus sealer.[21]

Furthermore, Tasdemir et al., reported that Epoxy resin based-sealers, such as AH Plus, offer moderate resistance to removal due to their deeper penetration into the dentinal tubules, whereas bioactive sealers like Ceraseal demonstrate the highest resistance, owing to their chemical bonding and crystal formation with dentin.[13]

Dem et al., investigated the push out bond strength of AH plus, GuttaFlow 2 and GuttaFlow Bioseal and concluded that AH plus had the highest push out bond strength as compared to GuttaFlow bioseal, possibly due to development of covalent bond.[22] With this we can conclude the difficulties faced during retreatment of AH Plus.

The current findings are consistent with previously mentioned research, which reported that epoxy resin-based sealers exhibit moderate residual material during retreatment, confirming their intermediate retreatability.

In this study, Group II- Silicone based sealer demonstrated the lowest residual obturating material (1.49 ± 0.82 mm²), making it the easiest sealer to remove when compared to Group I and III. The statistically significant difference between Group II- Silicone based sealer when compared to Group I- Epoxy resin based and Group III- Calcium silicate based ($p < 0.05$) confirms its superior retreatability.

According to Donoso et al., silicone-based sealers like GuttaFlow Bioseal show lower adhesion to dentin due to their hydrophobic nature, making them more susceptible to detachment during mechanical instrumentation.[23]

Additionally, Schäfer et al, found that GuttaFlow Bioseal sealer achieves limited penetration into dentinal tubules, which facilitates its removal during retreatment.[24]

Üstün et al., further corroborated these findings, highlighting that silicone-based sealers show reduced dentinal adhesion, which improves their retreatability.[25]

Thus, the superior retreatability of GuttaFlow Bioseal can be attributed to its hydrophobic, silicone-based composition and limited interaction with dentinal tubules, making it the most easily removable sealer among the groups tested. Hence, the results of the above quoted studies are in accordance with the result of our study.[26]

Previous studies, stated that the apical third of the root has more amount of remaining filling material as there is increased anatomical variability, making it impossible to direct retreatment rotary instruments against entire root canal walls.[15, 27]

Schirrmeister et al. reported that during obturation, the apical third frequently receives greater compaction of filling materials to achieve a reliable apical seal, especially when using techniques such as warm vertical condensation. As this method was employed in the present study, it may have contributed to the increased difficulty in removing obturating material during retreatment.[28]

Harak Chand Branwal et al. concluded that the greater amount of residual material in the apical third may be attributed to the design of the ProTaper Universal Retreatment (PTUR) system, which possesses a larger taper and is thus more effective at cutting coronal dentin.(29) Additionally, the apical third often presents greater anatomical complexities, necessitating more extensive enlargement for adequate cleaning and shaping—factors that contribute to the difficulty in complete removal of obturating materials during retreatment.[30]

In terms of the time duration required for complete sealer removal during endodontic retreatment, Group II -Silicone based-sealer demonstrated the most efficient removal, necessitating the least amount of time. Group I- Epoxy resin-based sealer required a moderate amount of time for removal, while Group III- Calcium silicate-based sealer posed the greatest challenge, demanding the most extended duration for thorough removal.

One of the primary limitations of this study was the relatively small sample size but statistically enough samples, which may restrict the extent to which the findings can be generalized to a broader population. Additionally, the study was conducted using teeth with relatively straight root canals, which may not accurately represent clinical situations involving more complex or curved anatomies. Such anatomical variations could influence the effectiveness of retreatment procedures and

sealer removal outcomes. Moreover, the use of a gutta-percha solvent during retreatment may have contributed to the formation of a thin, softened layer of material adhering to the canal walls, potentially complicating the complete removal of obturation materials and influencing the accuracy of residual measurements

It is imperative for dental professionals to remain abreast of the latest advancements in endodontic materials and techniques, including sealers, rotary retreatment systems, solvents, obturation methods, and evaluation tools. A thorough understanding of these elements—their properties, clinical applications, and retrievability—is essential for devising effective treatment strategies and achieving favorable patient outcomes.

CONCLUSION

As per the conditions of this research study, complete debridement of the canal walls was not achievable with any of the groups. Amongst the three sealer tested, Group III - Calcium-Silicate-Based sealer, left behind the most amount of obturating material, especially in the apical third, suggesting that it is harder to remove. Group I- AH Plus sealer showed a moderate amount of remaining material, while Group II- GuttaFlow Bioseal sealer performed the best in terms of retreatability, leaving the least residue and least time consuming when compared to Group I and III.

The apical third consistently had more remanants of sealers than the middle or coronal thirds. This likely reflects how complex and harder to reach this area is during treatment, making complete cleaning more difficult.

These results point to the need for careful selection of sealer materials, especially when future retreatment might be needed. Clinicians should also be mindful of the anatomical challenges presented by the apical third.

To strengthen these findings, future studies with larger sample sizes and more varied root anatomies with different sealers and instruments would be helpful. This could lead to even better strategies for effective and predictable removal of filling materials in endodontic retreatment.

SUMMARY

This study was conducted to assess and compare the retreatability of root canals filled with three different sealer types—Epoxy resin-based (AH Plus), Silicone-based (GuttaFlow Bioseal), and Calcium silicate-based (Ceraseal)—using the ProTaper Universal Retreatment system.

A total of Forty five extracted human mandibular premolars were selected, prepared, and obturated using the continuous wave compaction technique. Following a 2-week incubation period, retreatment was carried out, and Cone-Beam Computed Tomography (CBCT) imaging was employed to quantify the remaining filling material in the coronal, middle, and apical thirds of the root canals.

Statistical analysis indicated that there were significant variations in the residual surface area of obturating materials**,** depending on the type of sealers used and the specific region of the root canals**.** Group III- Ceraseal**,** a calcium silicate-based sealer, demonstrated the highest levels of residual material post-retreatment, particularly in the apical third. This suggests lower retreatability, likely due to its bioactive properties and strong adhesion to dentin. Group I- AH Plus, an epoxy resin-based sealer, presented a moderate level of residue, indicating average retreatability. Group II- GuttaFlow Bioseal**,** a silicone-based sealer, left the least amount of material, suggesting it was the most easily removed during retreatment , likely due to its reduced bonding to the canal walls. Regardless of the sealer used, the apical third consistently retained more material than the middle and coronal thirds, highlighting the anatomical limitations and difficulty in accessing this region during retreatment.

In terms of the time duration required for complete sealer removal during endodontic retreatment, Group II (Silicone-based sealer) demonstrated the most efficient removal, necessitating the least amount of time. Group I (Epoxy resin-based sealer) required a moderate amount of time for removal, while Group III (Calcium silicate-based sealer) posed the greatest challenge, demanding the most extended duration for thorough removal.

The study concludes that the type of sealer and the anatomical location within the canal significantly affect retreatment efficacy. Silicone-based sealers are more amenable to removal, whereas calcium silicate-based sealers pose greater challenges to retreat. Additionally, the apical third remains the most resistant to complete debridement, emphasizing the need for careful material selection and advanced techniques in endodontic retreatment.

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ANNEXURE – I - ETHICAL APPROVAL CERTIFICATE

Research and Ethics Committee
KLE VK INSTITUTE OF DENTAL SCIENCES
A Constituent Unit of KLE Academy of Higher Education & Research
Accredited 'A' Grade by NAAC — Placed in Category 'A' by MHRD (GoI)
Nehru Nagar, Belagavi - 590 010, Karnataka State
☎: 0831-2470362 — Web: http://www.kledental-bgm.edu.in
FAX: 0831-2470640 — E-mail:principal@kledental-bgm.edu.in

Sl. No. : 1644

CERTIFICATE

This is to Certify that the synopsis titled

A Comparative Evaluation of Retreatability of Epoxy Resin, Silicone and Calcium Silicate Based Endodontic Sealers : An In-vitro Cone Beam Computed Tomography Analysis

Submitted by

Dr. IE0222001 *P. G. Student / Staff, Guided by* _____ *from Department of* Conservative Dentistry and Endodontics *has been critically evaluated by committee members and granted ethical clearance to conduct the above mentioned study*

Date :

Member Secretary
Research and Ethical Committee
KLEVK Institute of Dental Sciences
Belagavi

MEMBER SECRETARY
Research & Ethical Committee
KLEVK Institute of Dental Sciences
BELAGAVI.

Chairman
Research and Ethical Committee
KLEVK Institute of Dental Sciences
Belagavi

Chairman
Research and Ethical Committee
KLE VK Institute of Dental Sciences
Belgaum

ANNEXURE – II - BIOSTATISTICS CLEARANCE CERTIFICATE

K L E
VISHWANATH KATTI
INSTITUTE OF DENTAL SCIENCES,
(Constituent college of K.L.E. University, Belgaum)
J.N.M.C. Campus, Nehru Nagar Belagavi -590010 Karnataka, India.
Conservative Dentistry and Endodontics

BIOSTATISTICS CLEARANCE CERTIFICATE

This is to certify that the Biostatistics art of Dissertation/ Research work of **IE0222001**

Postgraduate student under the guidance of **MDS**

Professor, **Department, of Conservative Dentistry and Endodontics** entitled **"A Comparative Evaluation of Retreatability of Epoxy Resin, Silicone and Calcium Silicate Based Endodontic Sealers: An In-vitro Cone-Beam Computed Tomography Analysis"** has been done under my guidance and considered satisfactory.

Place: Belagavi

Date: 08.04.25

Name and signature of
Biostatistician

Dr. S. B. Javali. Ph.D.
Professor In Statistics
Department of Community Medicine
USM KLE International Medical Programme,
BELAGAVI-590010.

ANNEXURE – III - PLAGIARISM ACCEPTED LETTER

Scientific Correspondence and Review Committee

KLE VK Institute of Dental Sciences

A Constituent Unit of KLE Academy of Higher Education and Research
(Deemed-to-be-University u/s 3 of the UGC Act, 1956)
Nehru Nagar, Belagavi - 590 010, Karnataka State

Accredited 'A+' Grade by NAAC (3rd Cycle) Placed in Category 'A' by MHRD (GoI)

☎: 0831-2470362
FAX: 0831-2470640

Web: http://www.kledental-bgm.edu.in
E-mail:principal@kledental-bgm.edu.in

Date : 18/04/2025 Serial No. : 422

PLAGIARISM CHECK REPORT

Name of the Applicant : IE0222001
UG / PG / Ph.D / Staff : PG
Batch & Year : 2022-2025
Department : Department of Conservative and Endodontic Dentistry

The soft copy of Research Work / Manuscript by IE0222001 entitled
"A comparative evaluation of retreatability of Epoxy-resin, silicone & calcium silicate based endodontic sealers : An in-vitro cone-beam computated tomography analysis"
under the guidance of ....has been submitted for Anti-Plagiarism check to the Scientific Correspondence & Review Committee of KLE VK Institute of Dental Sciences using "Turn-it-in" software.

The scan has been carried out and the scanned output reveals a Similarity Index of .....2.....%, which is **within / not within** the acceptable limits of 10% as per the UGC guidelines.

18/4/2025

Member Secretary
Scientific Correspondence and Review Committee
KLEVK Institute of Dental Sciences
KAHER-Belagavi

Chairman
Scientific Correspondence and Review Committee
KLEVK Institute of Dental Sciences
KAHER - Belagavi