EVALUATION OF THE SEALING ABILITY OF GUTTA PERCHA WITH BIOROOT RCS, MTA FILLAPEX AND SEALAPEX – AN SEM STUDY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

MAY 2020

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY
CHENNAI

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"EVALUATION OF THE SEALING ABILITY OF GUTTA PERCHA WITH BIOROOT RCS, MTA FILLAPEX AND SEALAPEX – AN SEM STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. M. RAJASEKARAN M.D.S,** Professor, Department of Conservative Dentistry and Endodontics, Ragas Dental College and Hospital, Chennai.

Date: 31/01/2020

Place: Chennai

Dr. ANITHA VARGHESE

Post Graduate Student

Dept. of Conservative Dentistry & Endodontics,

Ragas Dental College and Hospital,

Chennai.

CERTIFICATE

This is to certify that this dissertation titled titled **"EVALUATION OF THE SEALING ABILITY OF GUTTA PERCHA WITH BIOROOT RCS, MTA FILLAPEX AND SEALAPEX – AN SEM STUDY"** is a bonafide record work done by **Dr. ANITHA VARGHESE**, under our guidance during her post graduate study period between 2017-2020.

This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY – CONSERVATIVE DENTISTRY AND ENDODONTICS, BRANCH IV**. It has not been submitted (partial or full) for the award of any other degree or diploma.

Guided by,

Dr. M. RAJASEKARAN, M.D.S,
Professor
Department of Conservative
Dentistry & Endodontics
Ragas Dental College & Hospital
Chennai.

Dr M RAJASEKARAN M.D.S.
PROFESSOR
Dept of Conservative Dentistry
& Endodontics

Dr. R. ANIL KUMAR, M.D.S,
Head of the Department
Department of Conservative
Dentistry & Endodontics
Ragas Dental College & Hospital
Chennai

Dr.R.ANIL KUMAR.M.D.S.,
PROFESSOR AND HEAD.
DEPARTMENT OF CONSERVATIVE
DENTISTRY & ENDODONTICS
RAGAS DENTAL COLLEGE & HOSPITAL
CHENNAI

Dr. N.S.AZHAGARASAN, M.D.S,
Principal
Ragas Dental College & Hospital
Chennai.

PRINCIPAL
RAGAS DENTAL COLLEGE AND HOSPITAL
UTHANDI, CHENNAI-600 119.

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY
CHENNAI

PLAGIARISM CERTIFICATE

This is to certify that this dissertation work titled **"EVALUATION OF THE SEALING ABILITY OF GUTTA PERCHA WITH BIOROOT RCS, MTA FILLAPEX AND SEALAPEX– AN SEM STUDY"** of the candidate **Dr. ANITHA VARGHESE** with Registration Number 241717152 for the award of **MASTER OF DENTAL SURGERY in BRANCH IV - CONSERVATIVE DENTISTRY AND ENDODONTICS.** I personally verified the urkund.com website for plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows **5 percentage** of plagiarism in the dissertation.

DATE: 31/01/2020

PLACE: Chennai.

Dr. ANITHA VARGHESE
Post Graduate Student
Department of Conservative
Dentistry and Endodontics,
Ragas Dental College and Hospital,
Chennai.

Guide & Supervisor sign with seal.

Dr. M. RAJASEKARAN, M.D.S,
Professor,
Department of Conservative
Dentistry and Endodontics,
Ragas Dental College and Hospital,
Chennai.

Dr M RAJASEKARAN M.D.S
PROFESSOR
Dept of Conservative Dentistry
& Endodontics

ACKNOWLEDGEMENT

*I take this opportunity to sincerely and whole heartedly thank my post graduate Teacher and my Guide Dr.**M. Rajasekaran,*** **M.D.S.,*****Professor,****Department of Conservative Dentistry and Endodontics, Ragas Dental College and Hospital, for his perseverance and constant motivation, guidance and support throughout my study period, which has helped me to complete my thesis work and moreover to be a better student and clinician.Without his whole hearted support and scholarly advice this thesis would not have been a reality.*

I extend my sincere thanks to ***Dr. Anil Kumar, M.D.S., HOD and Professor,****Department of Conservative Dentistry and Endodontics, Ragas Dental College and Hospital, who has been a support, a caring guide and also for his constant encouragement to widen the knowledge in various perspectives.*

I extend my sincere thanks to ***Dr. P. Shankar, M.D.S., Professor,*** *Ragas Dental College and Hospital, for his encouragement, support and guidance all throughout my study period.*

I extend my sincere thanks to ***Dr. C.S. Karumaran, M.D.S., Professor,*** *Ragas Dental College and Hospital, for his guidance and immense encouragement during the completion of my study.*

May I acknowledge my profound gratitude to ***Dr.B. Veni Ashok, M.D.S., Professor,*** *Ragas Dental College and Hospital who has been a great source of support to me throughout my P.G program and have encouraged me wholeheartedly for my thesis and also for clinical works .*

Dr. Shankar Narayan, M.D.S., Associate Professor, *Ragas Dental College and Hospital, for his constant friendly guidance, support and immense encouragement during the completion of this study and all throughout my study period.*

Dr.S.M. Venkatesan, M.D.S.,Associate Professor, *Ragas Dental College and Hospital, for his encouragement, support and constant guidance all throughout my study period.*

I would like to solemnly thank **Dr. B.Venkatesh, M.D.S., Reader,** *for all the help and support during my study period. I would also like to thank* **Dr. Nirmala, M.D.S., Senior lecturer** *for her friendly guidance and support.*

I also wish to thank the management of Ragas Dental College and Hospital, Chennai for their help and support.

*I remain ever grateful to all mybatchmates***, Dr. AkshayaBabu, Dr. AnuPriya G, Dr. B. V. Madhuri, Dr. Gayathri V., Dr. SaiSwathi R., Dr. Shalini Maria, Dr. SurajU***,for all their love and support.*

I thank my seniors, **Dr. Chinnu Rachel Koshy, Dr. Darlene Ann Johnson, Dr. P. Kavitha,***for their helpful guidance and to my* **juniors** *Dr. VisshnuVardhini, Dr. Jevina Christyfor their help.*

I would like to extend my heartfelt love and gratitude to my father – ***T. P. Varghese,*** *mother –* ***N. P. Geetha,*** *sister –* ***Sunitha Varghese,*** *brother in law-* ***Shine P. Jacob*** *and niece-* ***Serah Mariam Shine*** *for their love, understanding, constant support and encouragement throughout these years without which, I would not have reached where I am now.*

I extend my sincere thanks to ***Prof. Dr. Shanthi and Mr. G. Sivakumar****, for their kind guidance and help during my SEM analysis at Annamalai University, Chidambaram.*

My sincere thanks to ***Mr. K.Thavamani****for his support in DTP and Binding works. I extend my thanks to* ***Dr. Venkat****for his help in statistical work.*

Above all, I am thankful to the ***Lord my God****, for always guiding me and keepingme safe and blessing me with these wonderful people in my life.*

LIST OF ABBREVATIONS

S.NO	ABBREVATIONS	EXPANSION
1	NaOCL	Sodium hypochlorite
2	EDTA	Ethylenediamine tetra acetic acid
3	MTA	Mineral Trioxide Aggregate
4	ZOE	Zinc Oxide Eugenol
5	SEM	Scanning Electron Microcope
6	X	Magnification
7	RCS	Root Canal Sealer
8	%	Percentage
9	kv	Kilovoltage
10	µm	Micro meter
11	SPSS	Statistical Package for Social Sciences software
12	SD	Standard Deviation

CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

	(500X)

Introduction

INTRODUCTION

The goal of endodontic therapy is to completely eliminate bacterial load from the pulpal canals and fill the root canal system three dimensionally. The three-dimensional obturation of root canal system, is widely accepted as one of the major determinants for the success of root canal treatment. An inadequate root canal filling during obturation results in the re- entry and re-growth of microorganisms in the root canal, which causes irritation to the periapical tissue and compromises the treatment outcomes.[1] Though different materials are available for root canal obturation, the use of gutta-percha cones along with a root canal sealer, still remains as the accepted material of choice.[2]

As the root canal system is very complex in nature, pulp tissue and inorganic debris remaining in areas where the instruments and irrigation solutions cannot easily access during the endodontic treatment procedure are left undisturbed. These serve as a source of nutrition for the microorganisms surviving in the root canal, resulting in their growth and spread to the periradicular areas through the interface between the sealer and dentin.[3] Microleakage is one of the major causes for endodontic treatment failure, which occurs mainly due to poor adaptation between the gutta-percha and the sealer, the sealer and the dentin or through certain voids that may be present within the sealer. Hence it is essential to use an effective root canal sealer in order to fill in the irregularities and also to penetrate into the dentinal tubules for obtaining a 3- dimensional, hermetic seal. It is also important that the root canal sealers should promote adherence between the gutta-percha and dentinal walls for preventing the occurrence of gaps or voids at the sealer-dentine interface.[4]

The long term success of endodontic therapy depends on a completely sealed root filling after root canal obturation. Poorly filled areas in the root canal system act as a source of bacterial growth and accounts for about 58% of endodontic treatment failures Wide varieties of sealers have been used in combination with gutta-percha for obtaining the hermetic seal.[2]

Grossman described an ideal root canal sealer as the one that, provides an excellent hermetic seal when set; is tacky when mixed to provide adequate adhesion between itself and the root canal walls; does not shrink upon setting; is radiopaque; is tissue tolerant; is non staining and dimensionally stable.

Currently available commercial root canal sealers can be broadly categorized as: ZOE- based sealers, non- eugenol based sealers, calcium hydroxide- based sealers, resin-based sealers, glass ionomer- based sealers, silicone- based sealers and more recently introduced, calcium silicate based root canal sealers.[4]

Traditionally, endodontic sealers based on ZOE were used, but the major disadvantage with them was the poor sealing efficacy and bonding ability to both the core material as well as the root canal wall. Various modifications have been made in the sealer chemistry and formulation to improve the penetration and bond strength of sealers.[5]

ZOE sealers have a long history of successful use in Endodontics for root canal obturation for over a 100 years, but gets resorbed if it is extruded into the periapical tissue. It has a prolonged setting time, exhibits high solubility, undergoes setting shrinkage and can even stain the tooth structure. The indication of using zinc oxide eugenol sealer is related to its antimicrobial activity and popularity among clinicians, especially because it can be used with the thermoplasticized obturation technique also.[4] But studies have shown that, eugenol may leak from the zinc oxide eugenol sealers, which exerts certain toxic effects in the periapex and also decrease the transmission in the nerve fibres. This effect is persistent even after the setting of the material.

Calcium hydroxide sealers are shown to exhibit antimicrobial activity, as well as osteogenic and cementogenic potential, which is exerted via the leaching of calcium and hydroxyl ions into the surrounding tissues. The rationale for incorporation of calcium hydroxide to root canal sealers is derived from observations of the activity of cavity liners and bases containing calcium hydroxide, mainly due to their antibacterial and tissue regenerating ability.[6] Solubility is required for the release of calcium hydroxide and its sustained activity which is not consistent with the criteria of an ideal root canal sealer. Sealapex is a calcium hydroxide based sealer that has good biological properties and apical sealing capacity. The original composition of the material has been modified by the manufacturer by the addition of bismuth trioxide for improving its radiopacity and increasing its shelf life.[7] Calcium hydroxide based sealers exhibit a property of dissolution when it comes in contact with the periradicular tissues, similar to that of zinc oxide eugenol based and glass ionomer based sealers.[4]

Resin sealers also have been in use for a long period. It provides a good adhesion to the dentin walls and does not contain eugenol as a component. AH26 is a slow setting epoxy resin based sealer, that was shown to release formaldehyde when setting. A modified formulation of AH26, is AH Plus which on setting does not cause a release of formaldehyde. It does not resorb easily and may also produce a short-term inflammatory response. Studies have shown that on immersion in water for a period of 30 days, AH Plus exhibits a slight shrinkage, even though it meets the criteria of ISO 6876/2001.[4] EndoREZ is a dual cure methacrylate resin-based sealer with hydrophilic properties, that has shown to bond with the canal walls as well as the core material.

However, because of hydrophobic nature of the gutta percha, the root canal sealers have a tendency to pull away from it upon setting. In order to overcome these shortcomings, various new sealer systems are being introduced to enhance and improve their sealing abilities.[2]

Bioceramics are inorganic, nonmetallic and biocompatible materials having similar mechanical properties to that of the dental hard tissues. They are chemically stable, non-corrosive and interact well with the organic tissue. These sealers were developed as they could induce bioactivity on the material surface when it comes in contact with tissue fluids. Tricalcium silicate hydration with the phosphates present in tissue fluids results in the formation of calcium hydroxide. An interaction of these materials with the dentin has been termed as the mineral infiltration zone.[8] Newer bioceramic sealers have shown to possess a very high bond strength with dentin walls, owing to the formation of hydroxyapatite crystals. Bioroot RCS and MTA Fillapex are bioceramic based sealers with basic differences in its composition.[2]

Tricalcium silicate-based sealers have been introduced by Holland et al., after the increase in popularity of mineral trioxide aggregate due to its calcium releasing ability and bioactivity.[5] The first sealer based on tricalcium silicate was MTA Fillapex, which is mainly composed of a salicylate resin matrix, silica and mineral trioxide aggregate being a minor component. Although the main scope of using a tricalcium silicate–based sealer is the release of calcium hydroxide from the material, MTA Fillapex has been shown to be inert and no calcium hydroxide was formed when the material set and also exhibits low calcium ion release in solution. However, MTA Fillapex complies with ISO 6876 and is also stable when used with warm vertical compaction techniques.[8]

More recently, a new water- based, tricalcium silicate-based sealer was introduced which is BioRoot RCS. It is composed of tricalcium silicate and zirconium oxide. BioRoot RCS releases calcium hydroxide after setting, which was absent in MTA Fillapex.[5] BioRootRCS is a water based sealer and hence, it should be used with a single-cone obturation technique rather than warm vertical compaction because the chemical properties of the sealer are changed when heated.[8]

According to Erickson, penetration of root canal sealers into dentinal tubules is essential to achieve a good bond strength. The stability of the bond formed between the root dentin and the gutta-percha interface reduced the failure associated with leakage of the material. Evaluation of the sealing ability of the sealer to both root dentin wall and gutta percha has been considered as an important parameter to assess, with the introduction of each new sealer.[5]

The aim of the present in vitro scanning electron microscopic study is to determine the sealing ability of gutta percha with a tricalcium silicate based sealer (Bioroot RCS), a salicylate resin based sealer (MTA Fillapex) and a calcium hydroxide based sealer (Sealapex) to the root dentine.

Aim and Objectives

AIM AND OBJECTIVES

AIM :

Aim of this in vitro study was to evaluate the sealing ability of three endodontic sealers, BioRoot RCS (a tricalcium silicate based sealer), MTA Fillapex (a salicylate resin based sealer) and Sealapex (a calcium hydroxide based sealer) with gutta-percha cones to the dentinal walls, using scanning electron microscopy.

OBJECTIVES:

1. To evaluate the sealing ability of BioRoot RCS, MTA Fillapex, Sealapex and ZOE sealers at the cervical, middle and apical thirds.
2. To compare the sealing ability of BioRoot RCS, MTA Fillapex, Sealapex and ZOE root canal sealers.
3. To evaluate which experimental sealer shows more gap formation and less sealing ability and which ones show less gap formation and more sealing ability.

Review of Literature

REVIEW OF LITERATURE

ERIC J. HOVLAND et al (1985)[9] compared Sealapex with two other root canal sealers for leakage in gutta-percha filled extracted teeth using a silver stain technique. The extent of leakage *in vitro* in the root canal systems over a 30-day period between the three root canal sealers was not statistically different. However, each sealer group leaked significantly less than the control group filled with gutta-percha only. The results support previous findings that a sealer with gutta-percha prevents apical leakage of the root canal system.

Bradley H. Gettleman et al (1991)[10] assessed the influence of a smear layer on the adhesion of sealer cements likeAH26, Sultan, and Sealapex to dentin. The results show significant differences ($p < 0.001$) among AH26, Sultan, and Sealapex, with AH26 being the strongest and Sealapex being the weakest. The only significant difference with regard to the presence or absence of the smear layer was found with AH26, which had a stronger bond when the smear layer was removed.

Kwang-Won Lee et al (2002)[11] compared four classes of endodontic sealers (Kerr, a ZOE-based sealer; Sealapex, a calcium hydroxide-based sealer; AH 26, an epoxy resin based system; and Ketac-Endo, a glass-ionomer based sealer) for their ability to bond to dentin or gutta-percha. The results indicated that sealant bond strengths to dentin were: Kerr 0.13 -0.02; Sealapex 0.30 - 0.08; Ketac-Endo 0.80 - 0.24; AH 26 2.06 - 0.53 MPa. The latter two were significantly different ($p < 0.05$) from the first two sealers and from themselves. The sealant bond strength to gutta-percha, from lowest to highest were: Ketac- Endo 0.19 - 0.01; Sealapex 0.22 - 0.01; Kerr 1.07 -0.19; AH 26 2.93 - 0.29 MPa. AH 26 gave the significantly highest bonds to gutta-percha.

Gustavo De-Deus et al (2003)[12] compared the depth of tubular dentinal penetration of sealer in three filling techniques. Seventy two teeth maxillary central incisors were instrumented and randomly divided in three groups A, B and C and obturated as following: A: lateral condensation; B: single cone technique and C: warm vertical compaction of gutta percha. Each sample was sectioned longitudinally and prepared for SEM analysis. They concluded that the samples filled by warm vertical compaction of gutta-percha presented significantly deeper tubular sealer penetration than lateral condensation and single cone techniques.

K. Mamootil et al (2007)[13] compared the depth and consistency of penetration of three different root canal sealer cements into dentinal tubules in extracted teeth and measured the penetration of an epoxy resin-based sealer cement in vivo. Root canals of 50 extracted human pre-molar teeth were prepared and obturated using three different sealer cements based on epoxy resin(AH26), zinc oxide eugenol (Pulp Canal Sealer EWT) and methacrylate resin (EndoREZ). Five teeth filled without sealer were used as controls. Teeth were sectioned and prepared for observation using scanning electron microscopy. The depth and consistency of dentinal tubule penetration of sealer cements appears to be influenced by the chemical and physical characteristics of the materials. Resin-based sealers displayed deeper and more consistent penetration.

Norberto Batista de Faria-Júnior et al (2010)[14] evaluated the flow rate of the Acroseal, AH Plus, Endomethasone N, Sealapex, and ActiV GP according to the standards of the ISO specification 6876/2001. It was concluded that only the Endomethasone N did not conform to ISO Specification that requires that a sealer shall have a diameter of not less than 20 mm. The Sealapex achieved the greatest flow, but it did not differ from Activ GP and AH Plus (P>0.5).

Mirjana Vujašković et al (2010)[15] evaluated the adhesion of the root canal filling to dentin and gutta-percha using scanning electronic microscopy. The sealing ability of endodontic sealers to dentinal walls of the root canal was assessed in recently extracted human single canal premolars. Twenty teeth were prepared using the crown-down technique and irrigated with 3% NaOCl. A total of 20 samples were divided into two groups. The root canals were obturated using Ketac-Endo Aplicap and GutaFlow. The sealing ability and adhesion properties at the sealer-dentin interface were studied using SEM and the results were rated from 1 to 3; extremely good adhesion (rated 1), good adhesion (rated 2) and a relatively good adhesion (rated 3). They concluded that GuttaFlow had a strong sealing ability and excellent adhesion to dentinal walls and gutta-percha cones. Ketac-Endo showed excellent bond to dentin with a slightly weaker adhesion capacity to the gutta-percha cones in comparison to GuttaFlow.

Seyda Ersahan et al (2010)[16] evaluated the push-out bond strength of iRoot SP (Innovative Bioceramix, Vancouver, Canada) and compared it with that of other widely used root canal sealers. Sixty extracted human maxillary canines were sectioned transversally below the cement-enamel junction to obtain 120 4-mm-thick dentin disks that were randomly divided into four groups (n = 30) for treatment with one of four different root-canal sealers (iRoot SP, AH Plus, Sealapex, EndoREZ). Standardized cavities were prepared to simulate root canals, cavities were filled with sealer material, and push-out bond-strength testing was performed using a universal testing machine. Failure modes were assessed quantitatively under a stereomicroscope and morphologically under a scanning electron microscope. It was concluded that iRoot SP and AH Plus performed similarly and better than EndoREZ and Sealapex in terms of bond strength.

Vasconcelos et al (2010)[17] evaluated the sealing ability of five root canal sealers, including two experimental cements (MBP and MTA-Obtura) using the fluid filtration method. Teeth were divided into 5 study groups: G1-AH Plus; G2-Acroseal; G3-Sealapex; G4-MBP; G5-MTA-Obtura; and two controls. Chemical-mechanical preparation was performed with ProFile rotary nickel-titanium instruments 1 mm short of the apical foramen. The sealing ability was evaluated by fluid filtration at 15, 30, and 60 days. AH Plus and MBP had similar leakage values at 15 and 60days, alternating with significant reduction at 30 days, while the other materials showed progressive increase in leakage values. All sealers evaluated presented fluid leakage, with AH Plus and MBP showing the best results at the end of the experimental period. Acroseal, Sealapex, and MTA-Obtura presented increase in leakage values at longer observation periods.

João Eduardo Gomes-Filho et al (2011)[18] evaluated the apical sealability of Fillapex, Endo-CPM-Sealer and Sealapex. Ninety-four freshly extracted single-rooted teeth were selected and decoronated. The teeth were randomly divided in groups of 10 specimens each according to the sealer, and the canals were filled using the single cone technique and one of the sealers. Four additional teeth were used as controls. The teeth were submitted to dye leakage with Rhodamine B. It was concluded that Fillapex and Sealapex were able to prevent apical dye leakage differently from Endo-CPM-Sealer.

Eric Balguerie et al (2011)[19] assessed the tubular adaptation and penetration depth and the adaptation to the root canal walls in the apical, middle, and coronal third of the root canal of 5 different sealers (AH Plus, Acroseal, Endobtur, Ketac Endo, RSA) used in combination with softened gutta-percha cones, in vitro. Fifty-two single-rooted teeth were prepared and filled with 5 different sealers and softened gutta-percha cones. Thereafter, the roots were cross sectioned and prepared for scanning electron microscopic evaluation. Adaptation of the sealer to the root canal and tubular walls and tubular penetration were assessed. It was concluded that the tubular penetration and adaptation varies with the different physical and chemical properties of the sealers used. AH Plus showed the most optimal tubular penetration and adaptation to the root canal wall of the sealers tested.

Seyda Ersahan et al (2012)[20] assessed and compared the water sorption, solubility and apical sealing ability of iRoot SP and three other widely used root canal sealers, by immersing standardized samples of calcium silicate- (iRoot SP), calcium hydroxide- (Sealapex), methacrylate resin- (EndoREZ) and epoxy resin- (AH Plus) based sealers in distilled water and measuring weight gain and weight loss at 6 h, 24 h and daily for 14 days. EndoREZ exhibited the highest water sorption, followed by iRoot SP, Sealapex and AH Plus. Sealapex exhibited significantly higher solubility than the other sealers, whereas no significant differences in solubility levels were observed between the other three sealers tested. In conclusion, all tested sealers except Sealapex met the ANSI/ADA’s requirements for solubility and no difference was found between AH Plus and iRoot SP in terms of apical sealing ability.

I**.S. Sönmez et al (2012)**[21] evaluated the apical microleakage of a new MTA-based sealer; MTA Fillapex (Angelus) and compare it with ProRoot MTA (Dentsply) and AH Plus (Dentsply). 51 single-rooted teeth were selected and the roots were prepared using rotary system. The samples were divided randomly into 3 groups (n=15). Six roots were used as positive and negative controls. The teeth were obturated with respectively; 1. AH Plus and gutta percha (DiaDent); 2. MTA Fillapex and gutta percha; 3. ProRoot MTA. 51 single-rooted teeth were selected and the roots were prepared using rotary system. The samples were divided randomly into 3 groups (n=15). Six roots were used as positive and negative controls. The teeth were obturated with respectively; 1. AH Plus and gutta percha; 2. MTA Fillapex and gutta percha ; 3. ProRoot MTA. MTA Fillapex group had significantly higher microleakage values ($p<0.05$). There was no statistically significant differences among MTA and AH Plus groups ($p>0.05$). It was concluded that he sealing ability of AH Plus and MTA is similar whilst MTA Fillapex had shown more microleakage than the other two materials.

Kumar N S et al (2013)[22] evaluated the apical sealing ability and adaptation of two resin-based sealers to dentin. Fifty freshly extracted mandibular first premolars were taken and sectioned at the cementoenamel junction. Thirty teeth were subjected to a leakage study by the resin infiltration method with two groups of 10 teeth each. Twenty teeth were divided into two groups and obturated as in the leakage study and subjected to a scanning electronic microscopy analysis for adaptation and resin depth penetration. It was found that both the sealers produced apical leakage to a certain extent. The adaptation and resin sealer penetration in the coronal and middle thirds was better than in the apical third of the root canal under SEM observation.

Piedad S. Cañadas et al (2014)[7] compared the physicochemical properties and interfacial adaptation to canal walls of Endo-CPM-Sealer, Sealapex and Activ GP with the well-established AH Plus sealer. All sealers, except for ActiVGP, were alkaline and all of them fulfilled the ANSI/ADA requirements for radiopacity and solubility. Regarding the interfacial adaptation, AH Plus was superior to the others considering the adaptation to the bovine root canal walls.

Daniela Kok et al (2014)[23] assessed the penetrability of two endodontic sealers (AH Plus and MTA Fillapex) into dentinal tubules, submitted to endodontic treatment and subsequently to endodontic retreatment. All specimens were filled with gutta-percha cones using the lateral compaction technique. The specimens were submitted to endodontic retreatment using Pro- Taper Retreatment system, re-prepared up to F5 instruments and filled with gutta-percha cones and the same sealer used during endodontic retreatment. Fluorescein dye (green) was incorporated to the sealer in order to distinguish from the first filling. The roots were sectioned 2 mm from the apex and assessed by CLSM. In retreatment cases, none of the sealers were able to penetrate into dentin tubules. It can be concluded that sealer penetrability is high during endodontic treatment. However, MTA Fillapex and AH Plus do not penetrate into dentinal tubules after endodontic retreatment.

R. Viapiana et al (2015)[5] investigated the ability of BioRoot RCS, a tricalcium silicate-based root canal sealer and AH Plus to effectively fill the root canals of contralateral teeth using three evaluation methods. The prepared root canals of ten pairs of contralateral mandibular premolar teeth were filled with gutta-percha and sealer using lateral compaction. The percentage of voids within the root canal was assessed by micro-computed tomography, whilst sealing ability was investigated by fluid transport and leakage of fluorescent microspheres. They concluded from the MicroCT analysis that there was a higher void volume for BioRoot RCS. The other techniques did not show a difference between the sealing ability of the sealers.

Vikram Shetty et al (2015)[24] quantitatively analyzed the amount of dye leakage with AH26, Sealapex and Tubliseal sealers in endodonticaly treated teeth. A total of 36 extracted mandibular molar specimens were divided into three groups; Group I: Sealapex, Group II: Tubliseal, Group II: AH26 with 12 samples in each group. Obturations were done using respective sealers in the three different groups. Then, samples were subjected to spectro photometric analysis using a filter of 670 nm. It was concluded in this study that Tubliseal sealer showed least microleage compared with Sealapex and AH26 sealer.

Khader MA et al (2015)[25] compared the penetration depth of three root canal sealers most commonly available *viz.*, AH Plus, Tubli- Seal and Apexit Plus with different compositions using SEM. A total of 30 single-rooted mandibular premolars decoronated and the canal preparation done by step back technique was used for this study. 17% of ethylenediaminetetraacetic acid used as final flush. Prepared specimens were divided into three groups of 10 teeth each. After obturation, teeth were split longitudinally and viewed under SEM. It was concluded that Zinc oxide eugenol-based sealer (Tubli-Seal) shows less depth of penetration as compared to the calcium hydroxide-based sealer (Apexit Plus) and resin-based sealer (AH Plus).

Jardine AP et al (2015)[26] compared the effect of QMix, BioPure MTAD, 17 % EDTA, and saline on the penetrability of a resin-based sealer into dentinal tubules using a confocal laser scanning microscope and described the cleaning of root canal walls by SEM. Eighty distobuccal roots from upper molars were selected and randomly divided into four groups (n=20) before root canal preparation according to the solution used in the final rinse protocol. Sealer penetration was analyzed with Adobe Photoshop software. It was concluded that seventeen percent EDTA and QMix promoted sealer penetration superior to that achieved by BioPure MTAD and saline.

Lovejeet Ahuja (2016)[6] evaluated and compared the apical microleakage of a resin based sealer; Adseal with Mineral Trioxide Aggregate (MTA) based sealers; Pro root MTA and MTA Fillapex. 75 teeth were randomly divided into five groups with n=15; Group I - Gutta-percha and Adseal sealer; Group II - Gutta-percha and MTA Fillapex; Group III- Gutta-percha and Pro root MTA; Group IV- Gutta-percha without sealer (positive control group); Group V- Root canal remained empty (negative control).Roots were longitudinally split using a diamond disk. Linear apical dye penetration was measured under Stereomicroscope at 40X magnification. The results concluded that Adseal sealer showed minimal dye penetration followed by Pro root MTA and MTA Fillapex.

Levent Demiriz (2016)[27] evaluated the dentinal wall adaptation ability of MTA Fillapex root canal sealer using stereo electron microscope (SEM). Twenty four, single-rooted, human maxillary incisor teeth were used. All canals were prepared to a size F3 file. Teeth divided into two equal groups and one of the experimental groups was filled with AH Plus, and the other group was filled with MTA Fillapex using GP single cone as a core material. The roots were prepared for SEM evaluation and serial scanning electron photomicrographs were taken at ×50, ×100, ×500 and ×1000 magnifications. MTA Fillapex was found to have a similar dentinal wall adaptation ability as AH Plus.

Swapnika Polineni et al (2016)[28] this *in vitro* study evaluated and compared the marginal adaptation of three root canal sealers to root dentin. 30 single-rooted teeth were decoronated, and root canals were instrumented. The specimens were randomly divided into three groups. Group 1 -teeth were obturated with epoxy resin sealer, MM Seal. Group 2 - teeth were obturated with mineral trioxide aggregate based sealer, MTA Fillapex, Group 3 teeth were obturated with bioceramic sealer, EndoSequence BC sealer. The samples were vertically sectioned using hard tissue microtome and marginal adaptation of sealers to root dentin was evaluated under coronal and apical halves using SEM and marginal gap values were recorded. Coronal halves showed superior adaptation compared to apical halves in all the groups under SEM. It was concluded that the epoxy resin based MM Seal showed good marginal adaptation than other materials tested.

Rabab A. Gad et al (2016)[29] evaluated the sealing ability and quality of obturation when canal filled with gutta-percha and either mineral trioxide aggregate or AH Plus sealer with detection of any possible correlation between microleakage and voids. 30 maxillary one- rooted teeth were prepared and assigned to 3 experimental groups; group I: gutta-percha/AH Plus, group II:gutta-percha/MTA sealer, group III positive control group (n = 5) teeth unobturated, groupIV: negative control group (n = 5) teeth obturated with gutta percha, AH Plus sealer. After obturation, each tooth was prepared for fluid filtration assessment. Voids detection was performed through cross sectional analysis at three root levels. The results showed that sealing ability of MTA FillApex sealer showed higher parameters than AH Plus sealer even if it was not significant. It was concluded that MTA FillApex and AH Plus sealer can provide adequate seal with low voids percent. Voids percentage cannot be used as an indicator for sealing ability.

Widcha Asawaworarit et al (2016)[30] evaluated the apical sealing ability of tricalcium silicate-based (MTA Fillapex) and resin-based (AH Plus) sealers at 24 h, 7 days and 4 weeks. Four roots were selected randomly as controls, and the remaining 30 were randomly divided into 2 groups of 15 each: MTA Fillapex and gutta-percha (group 1) and AH Plus and gutta-percha (group 2) using a warm vertical compaction technique. From this study it was concluded that, the tricalcium silicate-based sealer promoted proper sealing when used for filling the root canals.

Issam Khalil et al (2016)[8] aimed to characterize and investigate the properties of a new tricalcium silicate–based sealer and verify its compliance to ISO 6876 (2012). A new tricalcium silicate–based sealer (Bio MM; St Joseph University, Beirut, Lebanon), BioRoot RCS (Septodont, St Maure de Fosses, France), and AH Plus (Dentsply, DeTrey, Konstanz, Germany) were investigated. Characterization using scanning electron microscopy, energy-dispersive spectroscopy, and X-ray diffraction analysis was performed. Bio MM interacted with physiologic solution, thus showing potential for bioactivity. Sealer properties were acceptable and comparable with other sealers available clinically.

Anisha Kumar et al (2016)[31] aimed to compare the area of voids in mineral trioxide aggregate (MTA) based, resin based, and zinc oxide eugenol based sealers when employed with SC obturation technique. Fifteen teeth were cleaned and shaped and divided into three groups for SC obturation using

MTA Fillapex,AH26, and Pulpdent sealers, respectively. The obturated teeth were sectioned at apical, middle, and coronal third, and area of voids in the sealer was assessed using a stereomicroscope and digital images and image software. It was found that single cone obturation with MTA Fillapex sealer showed void free apical and middle third sections, and had significantly least area of voids in the sealer followed by the one with AH26 sealer, whereas SC obturation with Pulpdent sealer had significantly most area of voids.

R. Krug et al (2016)[32] evaluated the radiographic technical quality of root canal treatment before and after the implementation of a nickel-titanium rotary preparation followed by a matching-taper single-cone obturation and to detect the procedural errors associated with this technique. It was concluded that the rotary root canal preparation followed by a matching-taper single-cone filling technique provides a reliable shaping of the root canal, with fewer procedural errors and a more acceptable filling quality in terms of length and homogeneity in the apical third. Less favourable results were achieved in the central and cervical parts of the root canals.

Anil K Tomer et al (2017)[1] evaluated and compared the apical microleakage of calcium hydroxide (Sealapex), Mineral Trioxide Aggregates (MTA Fillapex) and silicone based (Roekoseal) sealers. Extracted human single rooted teeth were decoronated at cementoenamel junction. The access cavities and biomechanical preparation were performed using endodontic rotary system and the teeth were randomly divided into three groups with n=10; Group I - Guttapercha and Sealapex sealer; Group II - Gutta-percha and MTA Fillapex; Group III- Gutta-percha and Roeko Seal; and negative control group as empty root canal. MTA Fillapex group showed maximum apical microleakage followed by Sealapex and Roeko Seal sealer.

Vimal Remy et al (2017)[33] aimed to compare the marginal adaptation and sealing ability of MTA-Fillapex, AH Plus and Endofill root canal sealers. Single rooted mandibular premolars were sectioned at the cement enamel junction using a low-speed diamond disc. Step-back technique was used to prepare root canals manually. Under SEM, marginal gap at sealer and root dentin interface were examined at coronal and apical halves of root canal. Among the three maximum marginal adaptations were seen with AH Plus sealer (4.10 ± 0.10) which is followed by Endofill sealer (1.44 ± 0.18) and MTA-Fillapex sealer (0.80 ± 0.22). Between the coronal and apical marginal adaptation, significant statistical difference ($p = 0.001$) was seen in AH Plus sealer. It was found that AH Plus sealer has a better marginal adaptation when compared with other sealers used.

F. Siboni et al (2017)[34] evaluated the chemical and physical properties of a tricalcium silicate root canal sealer containing povidone and polycarboxylate (BioRoot RCS), a calcium silicate MTA-based sealer containing a salicylate resin (MTA Fillapex), a traditional eugenol containing sealer (Pulp Canal Sealer) and an epoxy resin-based root canal sealer (AH Plus). Calcium release, pH, setting time, water sorption, volume of open pores, volume of impervious portion, apparent porosity and weight loss were measured. BioRoot RCS had bioactivity with calcium release, strong alkalizing activity and apatite forming ability, and adequate radiopacity. It was found that both tricalcium silicate-containing materials were associated with ion release, porosity, water sorption and solubility higher than AH Plus and Pulp Canal Sealer.

Haridas Das Adhikari et al (2017)[35] determined that which among the following root canal sealers- AH Plus, GuttaFlow and RealSeal provided a superior marginal adaptation with the core obturating material in the apical third region of root canals by using scanning electron microscopy. After sectioning longitudinally, apical third of the roots were observed under SEM dentin-sealer-core interface was focused. Marginal adaptation and interfacial gaps at core-sealer interface of all the samples were evaluated. They concluded that GuttaFlow showed better adaptation in the apical third of root canals.

Alessandra Timponi Goes Cruz et al (2017)[36] evaluated the effect of a calcium hydroxide (CH) dressing on the tubular penetration of two endodontic sealers, AH Plus (Dentsply Maillefer, Ballaigues, Switzerland) and MTA Fillapex (Angelus, Londrina, Brazil). They concluded that the CH dressing did not interfere with the apical penetration of both tested sealers, however, decreased the tubular penetration in the middle third of the AH Plus root canal fillings. Overall, MTA Fillapex presented higher tubular penetration than AH Plus obturations.

Claudio Poggio et al (2017)[37] evaluated and compared the cytotoxic effects of eight root canal sealers (BioRoot RCS, TotalFill BC Sealer, MTA Fillapex, Sealapex, AH Plus, Easy Seal, Pulp Canal Sealer, N2) on immortalized human gingival fibroblasts over a period of 24, 48 and 72 hours. Immortalized human gingival fibroblast-1 HGF-1 were incubated. Root canal sealers were then placed into sterile, cylindrical Teflon moulds. The extraction was made eluting the sealers in cell culture medium. In the present study only BioRoot RCS, TotalFill BC Sealer and AH Plus showed no cytotoxic effects at least in the first 24h. All the other sealers revealed moderately or severely cytotoxic activity during all the extraction times.

Srinidhi V. Ballullaya et al (2017)[38] Evaluated the microleakage in different root canal sealers like zinc oxide eugenol based sealer, Sealapex, AH Plus, MTA Plus, EndoRez, Endosequence BC. All the specimens were examined under stereomicroscope for microleakage and the obtained data were statistically analysed. Bio ceramic sealers being hydrophilic show better sealing ability compared to resin based and eugenol based sealers.

Farnaz Jafari et al (2017)[39] conducted a review of literature to discuss the composition, physicochemical properties, and clinical perspectives of calcium silicate based sealers. They concluded that the Calcium silicate based sealers showed suitable physical properties to be used as an endodontic sealer though its high solubility remains an important issue. They show good performance regarding calcium ion release, film thickness, and flowability.

Attur KM et al (2017)[40] studied the possible correlation of dentinal tubule penetration and microleakage by three root canal sealers: AH26, zinc oxide eugenol, and mineral trioxide aggregate using a dye leakage and scanning electron microscopy methods. Fifty‑one maxillary anterior teeth with completely formed apex divided into three groups. Root canals were enlarged till No. 60 K‑file using step‑back technique. Alternate 5.25% and 17% ethylenediaminetetraacetic acid irrigants were used and obturated with gutta‑percha and one of the three sealers: MTA, AH26, and ZOE. The extent of leakage was determined under stereomicroscope after immersion in methylene blue and also observed the tubular penetration of sealer under SEM.They found that AH26 had lower microleakage scores than the other sealers, and MTA demonstrated the least penetration.

Sampath Kumar Arikatla et al (2018)[41] evaluated the interfacial adaptation and penetration depth of Bioroot RCS and MTA Plus sealers into root dentin. A total of 60 single rooted mandibular premolar teeth were prepared using Pro Taper rotary NiTi files and were randomly divided into three groups (n = 20 each) according to the type of sealer used for obturation. The results showed that AH Plus sealer has significantly higher depth of penetration and minimum gaps than bioceramic sealers ($P < 0.05$) MTA Plus sealer exhibited significantly more interfacial gaps and less penetration depth than Bioroot RCS ($P < 0.05$).

Fabricio Guerrero et al (2018)[42] compared the porosity of two sealant cements, mineral trioxide aggregate (MTA) Fillapex and BioRoot root canal sealer. Sixteen samples were used in the study that were divided according to the composition of the materials used and were prepared according to the manufacturer's instructions. They were placed in silicone molds of 5 ± 0.1 mm in height and an internal diameter of 5 ± 0.1 mm; 24 h after its preparation, the samples were scanned through a micro computed tomography. The results obtained in computerized microtomography endodontic biomaterial samples concluded that MTA Fillapex has a lower porosity than BioRoot RCS.

Halenur Altan et al (2018)[43] aimed to compare the short and long term apical sealing ability of different root canal sealers. The coronal part of each tooth was removed and the root canals were prepared with NiTi rotary instruments. Teeth were divided into 5 study groups; Group I: MTA Fillapex; Group II: Sealapex and Group III: AH Plus (n=15) and negative and positive control groups (n=5). In the results, Sealapex and AH Plus showed significantly better sealing abilities than MTA Fillapex in the long term.

Emel Uzunoglu-€Ozy€urek et al (2018)[44] evaluated the effect of calcium hydroxide (Ca[OH]2) dressing on the dentinal tubule penetration of epoxy resin–based sealer (AH 26; Dentsply Maillefer, Ballaigues, Switzerland) and tricalcium silicate–based sealer (Bio- Root RCS; Septodont, Saint Maurdes Fosses, France). BioRoot RCS presented higher dentinal tubule penetration than AH 26 even in the presence of Ca(OH)2 residues. Ca(OH)2 remnants decreased both dentinal tubule penetration depth and the percentage of the tested sealers; however,a more drastic effect was observed for AH 26.

Gabriela Gonçalez Piai (2018)[45] evaluated the penetration of a new endodontic sealer into the dentinal tubules. 20 single-rooted teeth were selected. The crown was sectioned, and the canals were instrumented with a reciprocating system. The specimens were randomized into two groups (n =10) according to the endodontic sealer: AH Plus or Sealer Plus. All specimens were filled using the lateral compaction technique. Rhodamine B dye (red) was incorporated to the sealers to provide the fluorescence which will enable confocal laser scanning microscopy assessment. The root canal level affected the penetration of the sealer, but no statistically significant differences were found between the two experimental groups ($p > .05$). SP presented similar dentinal penetration and perimeter integrity to the gold standard (AP).

Kaveri Baruah et al (2018)[46] compared the apical sealability of mineral trioxide aggregate (MTA) Fillapex and Endosequence BC sealer at three different lengths of remaining gutta-percha after post space preparation. Apical leakage was assessed using dye penetration method under stereomicroscope. It was found that though less microleakage occurred, the bioceramic sealers could not totally eliminate leakage.

Sakshi Jain et al (2018)[47] conducted this *in vitro* scanning electron microscopic study to determine which of the commonly used root canal sealer among AH‑Plus, GuttaFlow, and RealSeal provides a superior marginal adaptation with the dentin in the apical third region of root canals. 30 human freshly extracted maxillary central incisors were biomechanically prepared, then divided equally into three groups and obturated with AH‑Plus, GuttaFlow, and RealSeal using single‑cone obturation technique. After sectioning longitudinally, apical third of the roots was observed under SEM; dentin‑sealer‑core interface was focused. Marginal adaptation and interfacial gaps at dentin‑sealer interface of all the samples were evaluated and analyzed statistically. It was found that the dentin‑sealer interfacial gap was minimum in GuttaFlow, it is better adapted to dentin in the apical third of root canals compared to AH‑Plus and RealSeal.

Asha Pius et al (2019)[2] evaluated and compared the sealer penetrability and gap formation of root canal sealer to root dentin filled with AH Plus, Sealapex, and BioRoot RCS. 27 teeth were randomly assigned to three groups based on the sealer, group I—AH Plus, group II—Sealapex and group III—BioRoot RCS, teeth were de-coronated and root canal therapy was done with Protaper gold rotary files and filled with the single-cone technique.

About 1-mm sections of apical, middle, and cervical third were taken using a water-cooled low-speed saw. All specimens are evaluated using a scanning electron microscope. The Bioceramic sealer revealed better sealer penetrability at the apical third and minimal gap formation compared to the epoxy resin-based and the calcium hydroxide-based sealer.

Materials and Methods

MATERIALS AND METHODS

ARMAMENTARIUM :

- 40 extracted mandibular premolars
- Endo access bur #16 (Dentsply)
- High speed airotor hand piece (NSK)
- K files- #10, 15, 20 (Mani, Inc.)
- Protaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland)
- X Smart (Dentsply Maillefer, Ballaigues, Switzerland)
- Normal Saline (Fresenius Kabi, India Pvt. Ltd)
- 2ml Syringe with 27 gauge needle (Unolock)
- Sodium hypochlorite 3% (Prime dental products, India)
- 17% EDTA (Desmear, Anabond Sterman Pharma.)
- Absorbent paper points (Meta biomed)
- 0.06 taper gutta percha, 25 (Diadent Group International, Korea)
- Spreader (Mani, Inc.)
- Glass slab and cement spatula
- Bioroot RCS (Septodont, France)
- MTA Fillapex (Angelus, Brazil)
- Sealapex (Sybron/Kerr Co. Ltd., Romulus, MI)
- Zinc oxide (DPI, India)

- Eugenol (DPI, India)
- Ethanol, absolute (Changshu Hongsheng Fine Chemical Co., Ltd.)
- De- ionised water (Evergreen laboratory reagent)
- Diamond disk
- Scanning Electron Microscope along with gold sputtering machine (JSM- IT 200; JFC- 1600 auto fine coater; JEOL Ltd.,Tokyo, Japan)

METHODOLOGY

A total of forty non carious, intact, human mandibular premolar teeth with a single root and single root canal, extracted for orthodontic reasons were selected. The teeth were cleaned of soft tissue and calculus. Access opening was done using endo access bur and a #10 K file was introduced into the root canal until its tip was just visible at the apical foramen. The root canals were instrumented through crown-down technique with ProTaper Universal rotary files using the following sequence: SX, S1, S2, F1, and F2, until the working length at the speed of 300 rpm and 1.5 N torque. The canals were irrigated with 2ml of 3% sodium hypochlorite during instrumentation and finally rinsed with 2ml of 17% EDTA acid for 5 minutes followed by 2ml of normal saline and then were dried with absorbent paper points. Then, the teeth were randomly divided into 4 experimental groups (Group I, II, III, IV) of 10 samples each.

All the four endodontic sealers were manipulated according to the manufacturer's instructions respectively and introduced into the root canal space with a size 35 finger spreader. The master cone, size 25.0.06 gutta percha was also coated with the sealer and inserted in the canal. After complete obturation, all root samples were kept moist by keeping them in gauze moistened with sterile saline for 1 week, to ensure complete setting of the sealer. The 40 experimental root specimens were painted with two layer of nail varnish at the coronal 1 mm and apical 2 mm. For assessment of gaps, the slices were dehydrated in an ascending ethanol series (70%, 80%, 90%, 100%).

Each root was then sectioned in cross sections using a diamond disk on a slow speed handpiece to obtain the dentin- root canal filling interface at the cervical, middle and apical thirds of the root respectively for all the IV groups. During sectioning, the specimens were subjected to continuous water cooling to prevent frictional heat, which minimizes smearing of core obturating materials that tend to hide areas of sealer as pointed by Vikram *et al*. The sections were then labelled accordingly. All the sectioned specimens were washed in 17% EDTA solution for 2 minutes followed by methanol and blot dried, which was then mounted on aluminum stubs and sputter coated with a 30μm thick gold layer in a fine-coat ion sputter (JFC- 1600 auto fine coater; JEOL Ltd., Tokyo, Japan) and examined with a scanning electron microscope (JSM- IT 200; JEOL Ltd., Tokyo, Japan) operating at a high accelerating voltage of 15.0 kV at different magnifications ranging from 50X to 1000X to achieve a representative area containing both gap- containing and gap - free regions and visualize a broader aspect of sample.

The adaptability at the sealer- dentinal wall interface was measured as the gap formation between the dentin surface and the sealer surface as seen from the SEM images in μm. The measurements at the cervical, middle and apical thirds were made using the IBM.SPSS statistics software 23.0 Version. The results for each group was recorded, tabulated and statistically analysed.

FLOW CHART

A total of forty mandibular premolar teeth were selected (n= 40)

↓

Standard access cavities were prepared using Endo access bur and working lengths were determined by placing a 10 size K-files in the canals

↓

Canals were instrumented with ProTaper Universal rotary files till size F2, with each tooth instrumented with multiple strokes coupled with irrigation by normal saline solution followed by 17% EDTA

↓

Teeth were randomly distributed into four groups

BioRoot RCS (n= 10)	**MTA Fillapex** (n= 10)	**Sealapex** (n= 10)	**ZOE** (n= 10)

↓

The root canals in each sample groups were obturated using the respective sealers, by the single cone technique. The sealers were mixed according to the manufacturer's instructions and coated in the canal using a spreader

↓

The teeth were dehydrated in an ascending ethanol series (70%, 80%, 90%, 100%) and 2mm thin sections were made using a water cooled diamond disc.

↓

All specimens were sputter coated with fine gold and viewed with a scanning electron microscope

↓

Results were obtained

↓

Data were statistically analysed using One Way ANOVA and Tukeys post hoc test

↓

Interpretation of data

Figures

FIGURE 1: TEETH SAMPLES

FIGURE 2 : ARMAMENTARIUM USED FOR BIOMECHANICAL PREPARATION

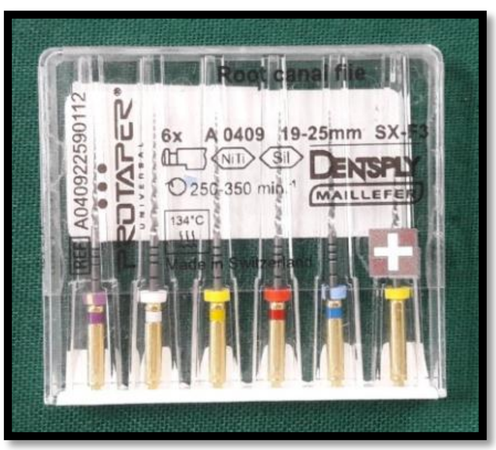


FIGURE 3: ARMAMENTARIUM FOR OBTURATION

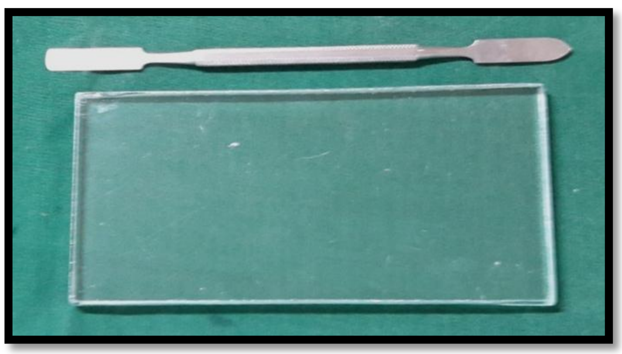


FIGURE 4: BIOROOT RCS SEALER

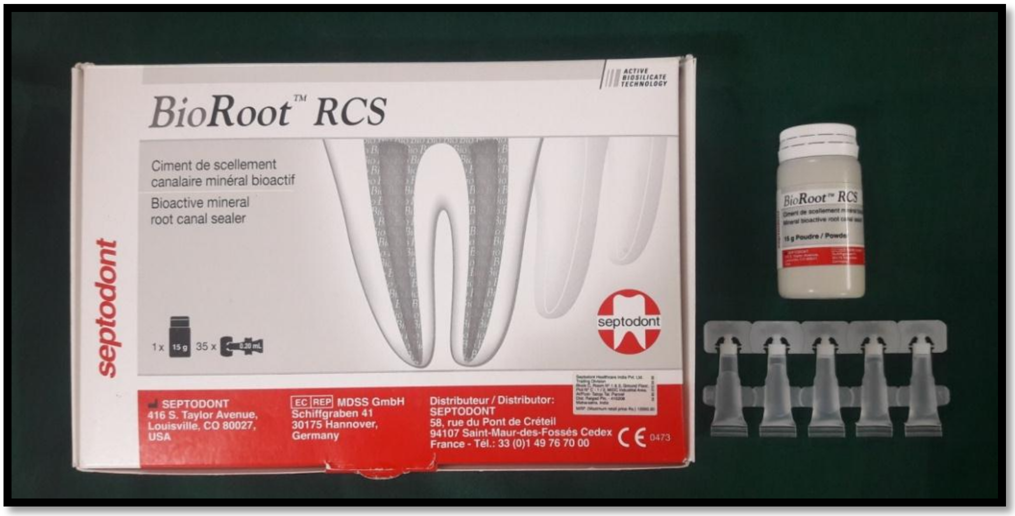


FIGURE 5: MTA FILLAPEX SEALER

FIGURE 6: SEALAPEX SEALER

FIGURE 7: ZINC OXIDE POWDER AND EUGENOL

FIGURE 8: SAMPLES AFTER SECTIONING

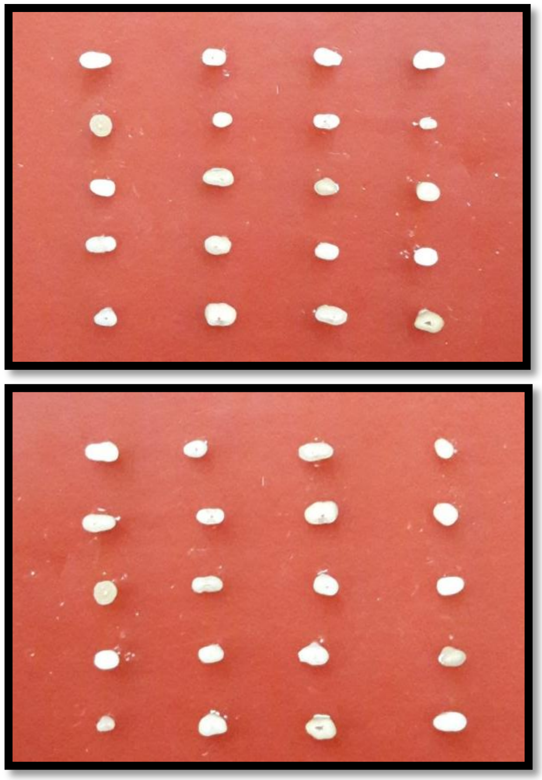


FIGURE 9: MOUNTED ON ALUMINUM STUBS

FIGURE 10: GOLD SPUTTERING IN JEOL; JFC- 1600

FIGURE 11: SEM UNIT (JEOL, JSM-IT 200)

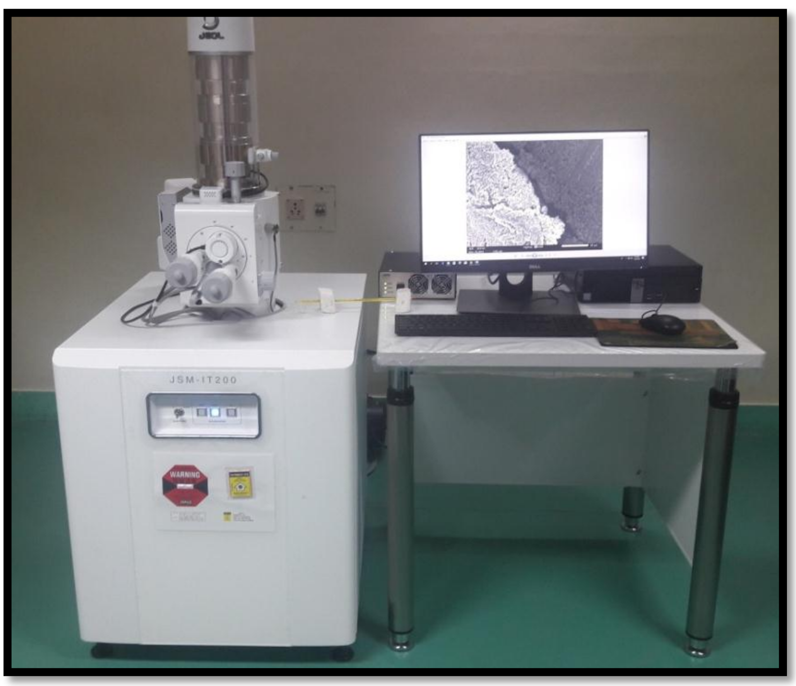


FIGURE 12: SEM IMAGES SHOWING ADAPTATION OF ZOE

Fig. 12.1- CERVICAL

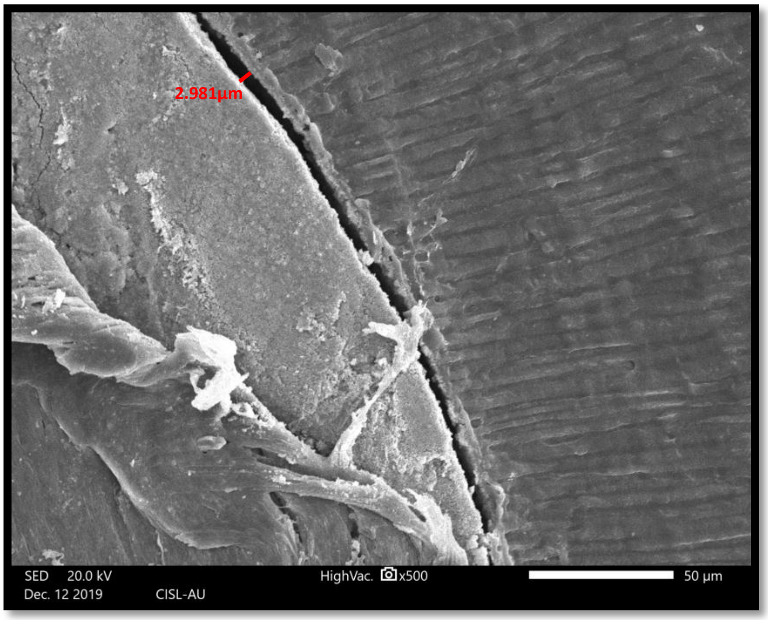


Fig. 12.2- MIDDLE

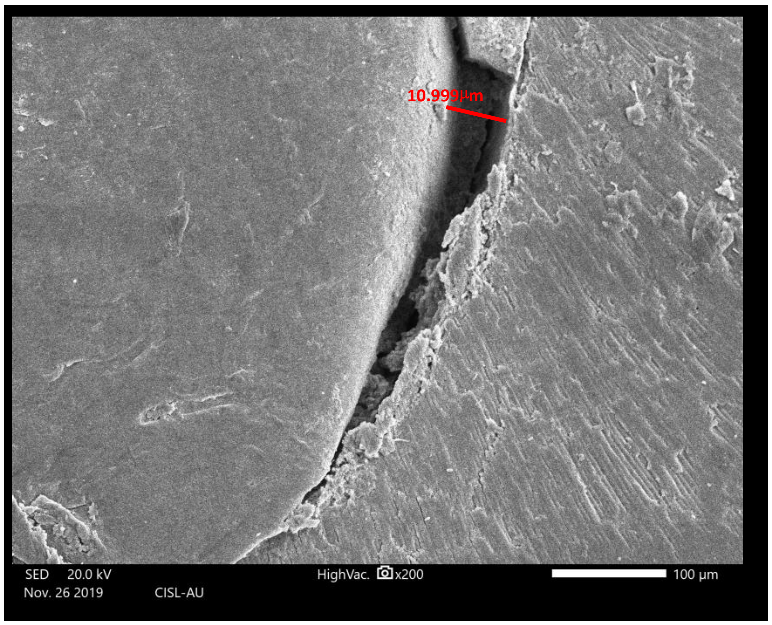


Fig. 12.3- APICAL

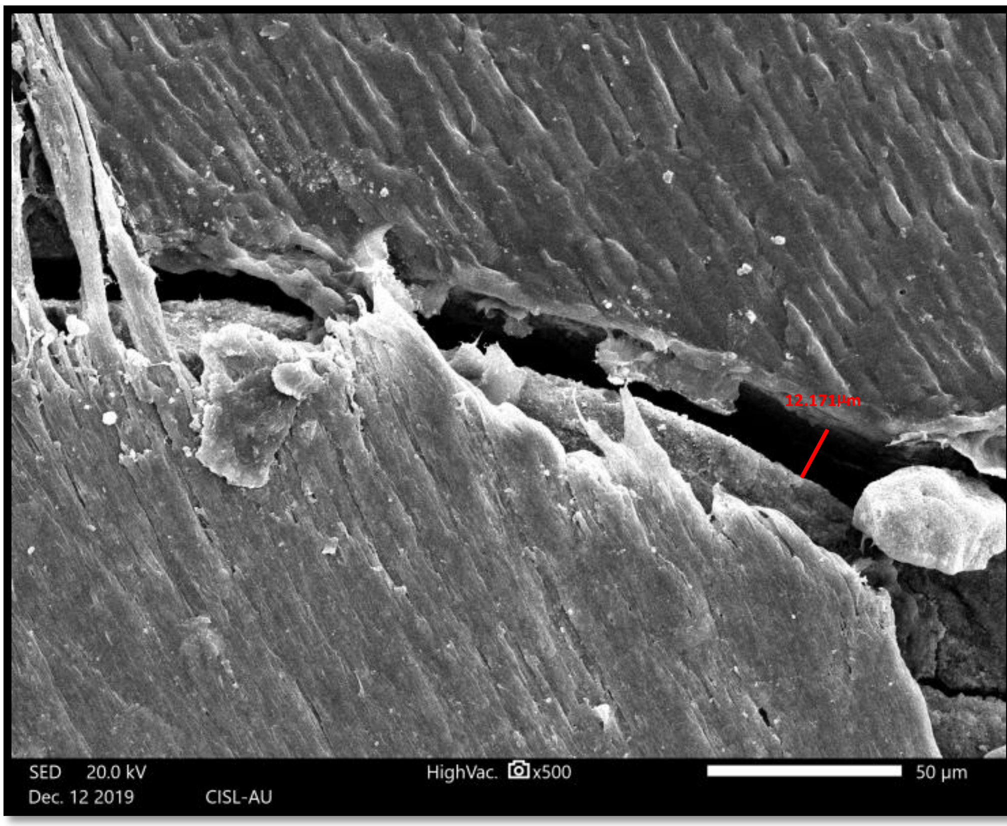


FIGURE 13: SEM IMAGES SHOWING ADAPTATION OF SEALAPEX

Fig. 13.1- CERVICAL

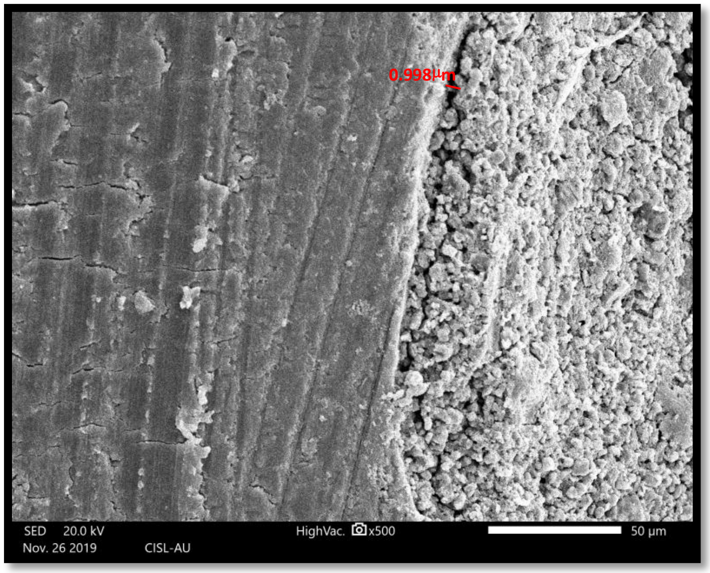


Fig. 13.2- MIDDLE

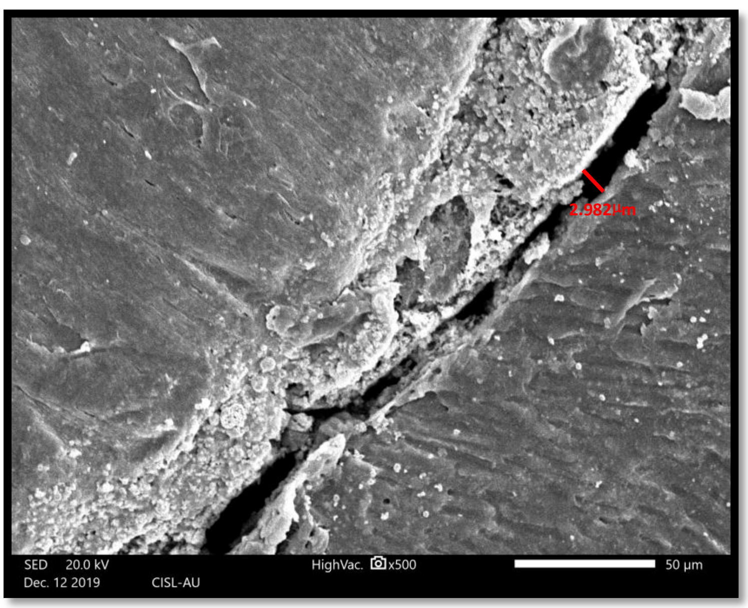


Fig. 13.3- APICAL

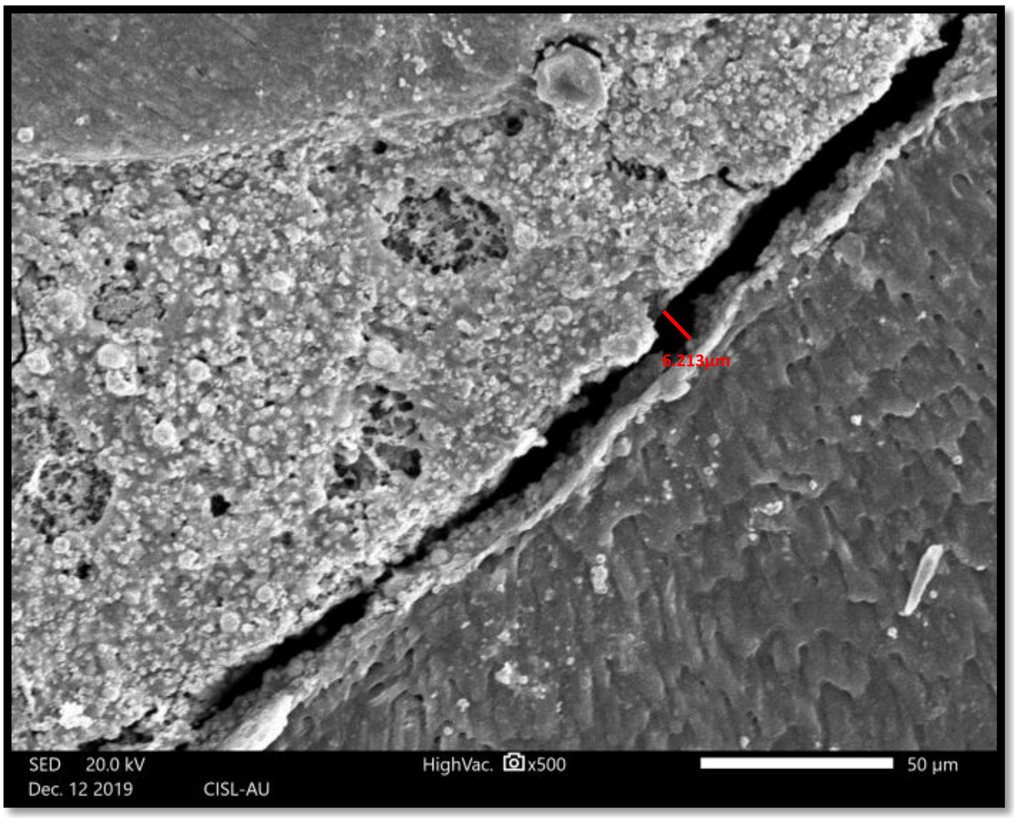


FIGURE 14: SEM IMAGES SHOWING ADAPTATION OF MTA FILLAPEX

Fig. 14.1- CERVICAL

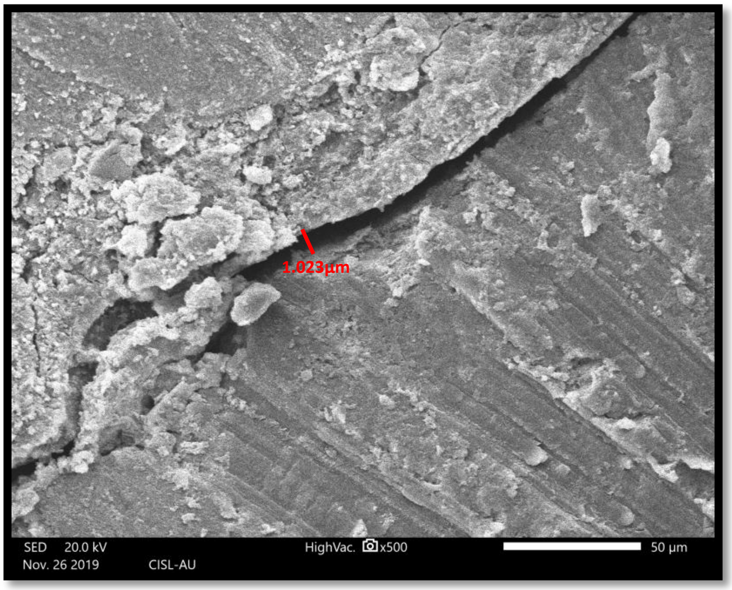


Fig. 14.2- MIDDLE

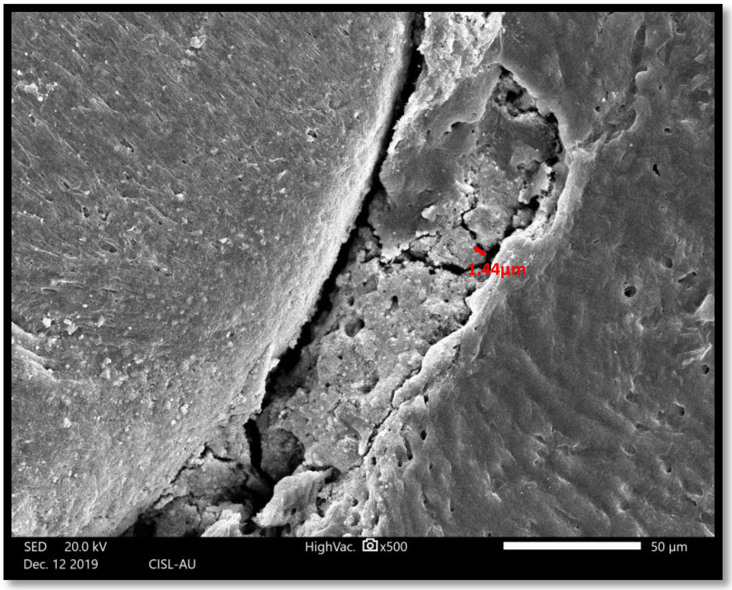


Fig. 14.3- APICAL

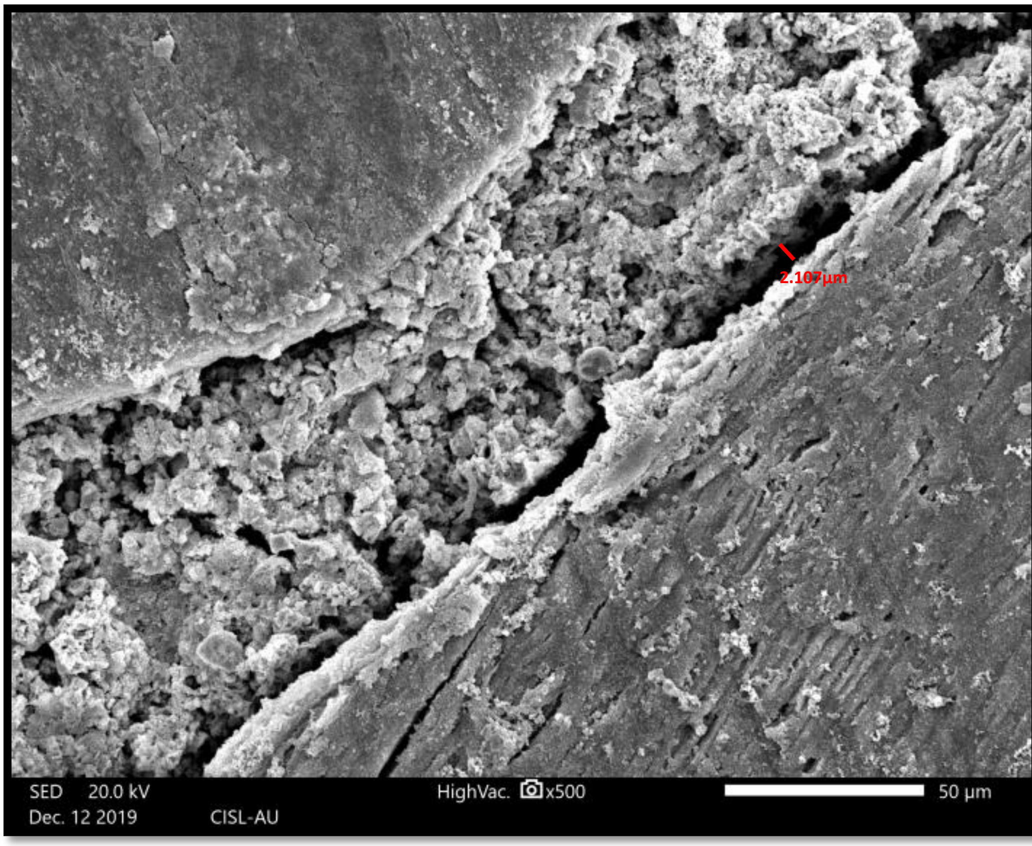


FIGURE 15: SEM IMAGES SHOWING ADAPTATION OF BIOROOT RCS

Fig. 15.1- CERVICAL

Fig. 15.2- MIDDLE

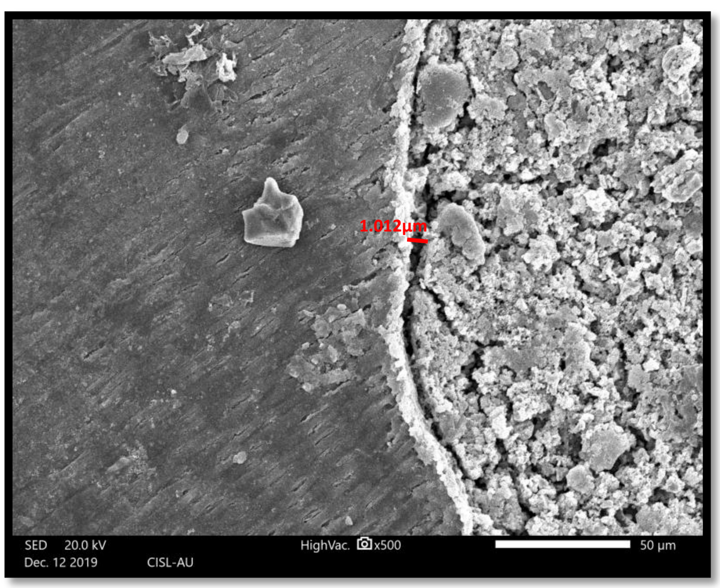
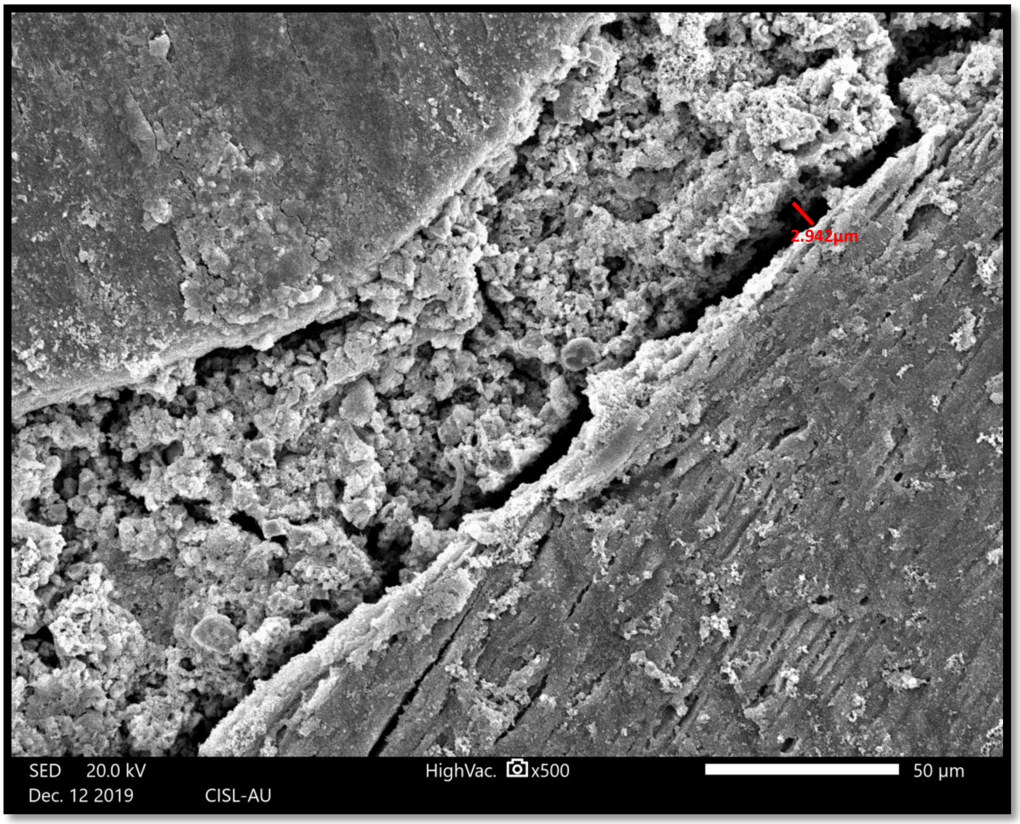


Fig. 15.3- APICAL



Results

RESULTS

This study was designed to analyse the sealing ability of gutta percha with three endodontic sealers; BioRoot RCS, MTA Fillapex and Sealapex using scanning electron microscopy analysis.The collected data were analysed with IBM.SPSS statistics software 23.0 Version. To describe about the data descriptive statistics the mean & S.D were used for continuous variables. To find the significant difference in the multivariate analysis the one way ANOVA with Tukey's Post-Hoc test was used. In both the above statistical tools the probability value .05 is considered as significant level.

The samples were divided into 4 groups:

Group 1, Guttapercha with BioRoot RCS (n=10).

G***roup 2***, Guttapercha with MTA Fillapex (n=10).

Group 3, Guttapercha with Sealapex (n=10).

Group 4, Control group, Guttapercha with ZOE (n=10).

Each experimental groups were evaluated at the cervical, middle and apical third levels for the gap formation of the four different sealers. The sealer penetration was estimated using the scanning electron microscope images by measuring the distance from the sealer-gutta percha interface to the dentinal wall in micrometers from each sample group with n=10, at a magnification range of 50X – 1,000 X.

Table 1a shows the mean and SD of the gap formation at the gutta percha- sealer interface to the dentinal wall in each group (BioRoot RCS, MTA Fillapex, Sealapex & ZOE) at the cervical third level. At the cervical third, ZOE shows the highest mean value [4.613(±1.0745)] , followed by MTA Fillapex [1.612(±0.213)], Sealapex [1.593(±0.172)] & BioRoot RCS [0.747(±0.177)]. The mean values obtained by Oneway ANOVA **(Table 1b)** shows that at the cervical third, the amount of gap formation between the sealer and root dentinal wall interface was highly significant ($P < 0.01$).

Post hoc was conducted as there was a significant difference among the groups **(Table 1 c)**. The multiple comparisons shows that, there is a highly significant difference between the control group of ZOE with the other 3 groups in the cervical third. [with BioRoot RCS (p=0.0005), MTA Fillapex (p=0.003) , Sealapex (p=0.003)].

This result show that none of the groups showed complete marginal adaptation at the sealer- dentin interface in the cervical third of the tested samples. This also shows that among the four test groups, ZOE has shown more gap formation; minimal sealing ability to the dentinal wall followed by MTA Fillapex, Sealapex and BioRoot RCS.

Table 2 a shows the mean and SD of the gap formation at the guttapercha- sealer interface to the dentinal wall in each group (BioRoot RCS, MTA Fillapex, Sealapex & ZOE) at the middle third level. At the middle third, ZOE shows the highest mean value [5.707(±1.020)], followed by Sealapex

[2.720(±0.396)], MTA Fillapex [2.312(±0.270)] &BioRoot RCS [1.309(±0.208)]. The mean values obtained by Oneway ANOVA **(Table 2 b)** shows that at the middle third, the amount of gap formation between the sealer and root dentinal wall interface was highly significant ($P < 0.01$).

Post hoc was conducted as there was a significant difference among the groups **(Table 2 c)**. The multiple comparisons show that, there is a highly significant difference between the control group of ZOE with the other 3 groups in the middle third. [with BioRoot RCS (p=0.0005), MTA Fillapex (p=0.001) , Sealapex (p=0.004)].

This result show that none of the groups showed complete marginal adaptation at the sealer- dentin interface in the middle third of the tested samples. This also shows that among the four test groups, ZOE has shown more gap formation; minimal sealing ability to the dentinal wall followed by Sealapex, MTA Fillapex and BioRoot RCS.

Table 3 a shows the mean and SD of the gap formation at the guttapercha- sealer interface to the dentinal wall in each group (BioRoot RCS, MTA Fillapex, Sealapex & ZOE) at the apical third level. At the apical third, ZOE shows the highest mean value [9.970(±1.158)] , followed by Sealapex [5.249(±0.669)], MTA Fillapex [4.088(±0.464)] &BioRoot RCS [2.417(±0.351)]. The mean values obtained by Oneway ANOVA **(Table 3 b)** shows that at the apical third, the amount of gap formation between the sealer and root dentinal wall interface was highly significant ($P < 0.01$).

Post hoc was conducted as there was a significant difference among the groups **(Table 3 c)**. The multiple comparisons show that, there is a highly significant difference between the control group of ZOE with the other 3 groups in the apical third. [with BioRoot RCS (p=0.0005), MTA Fillapex (p=0.0005) , Sealapex (p=0.0005)].

This result show that none of the groups showed complete marginal adaptation at the sealer- dentin interface in the apical third of the tested samples. This also shows that among the four test groups, ZOE has shown more gap formation; minimal sealing ability to the dentinal wall followed by Sealapex, MTA Fillapex and BioRoot RCS.

There were both gap-free and gap- containing regions at different levels in all groups. However, BioRoot RCS exhibited better apical marginal adaptation to dentinal wall than MTA Fillapex and Sealapex.

Tables and Graphs

TABLES

Table 1 a - DESCRIPTIVE STATISTICS OF GAP FORMATION BETWEEN DENTIN- SEALER INTERFACE AT THE CERVICAL THIRD, WITH THE DIFFERENT SEALERS USED.

Descriptives					
		N	Mean	S.D	Std. Error
CERVICAL	BioRoot RCS	10	.747	.560	.177
	MTA Fillapex	10	1.612	.674	.213
	Sealapex	10	1.593	.542	.172
	ZOE	10	4.613	3.398	1.075
	Total	40	2.141	2.263	.358

Table 1 b - RESULTS OF ONEWAY-ANOVA

Oneway – ANOVA						
		Sum of Squares	df	Mean Square	F	P-value
CERVICAL	Between Groups	86.324	3	28.775	9.129	0.0005 **
	Within Groups	113.476	36	3.152		
	Total	199.800	39			
** Highly Sig at P < 0.01 level						

Table 1 c – PAIRWISE TESTS *POST HOC* TESTS.

Post Hoc Tests - Multiple Comparisons - Tukey HSD					
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
CERVICAL	BioRoot RCS	MTA Fillapex	-.864600	.794	0.698 #
		Sealapex	-.846200	.794	0.712 #
		ZOE	-3.865600*	.794	0.0005 **
	MTA Fillapex	Sealapex	.018400	.794	1.000 #
		ZOE	-3.001000*	.794	0.003 **
	Sealapex	ZOE	-3.019400*	.794	0.003 **
# No Sig at P > 0.05 level ,** Highly Sig at P < 0.01 level					

Table 2 a - DESCRIPTIVE STATISTICS OF GAP FORMATION BETWEEN DENTIN- SEALER INTERFACE AT THE MIDDLE THIRD, WITH THE DIFFERENT SEALERS USED.

Descriptives					
MIDDLE	BioRoot RCS	10	1.309	.659	.208
	MTA Fillapex	10	2.312	.855	.270
	Sealapex	10	2.720	1.252	.396
	ZOE	10	5.707	3.226	1.020
	Total	40	3.012	2.405	.380

Table 2 b – **RESULTS OF ONEWAY-ANOVA**

Oneway - ANOVA						
		Sum of Squares	df	Mean Square	F	P-value
MIDDLE	Between Groups	107.399	3	35.800	10.900	0.0005 **
	Within Groups	118.234	36	3.284		
	Total	225.633	39			
** Highly Sig at P < 0.01 level						

Table 2 c – **PAIRWISE TESTS *POST HOC* TESTS**

Post Hoc Tests - Multiple Comparisons - Tukey HSD					
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
MIDDLE	BioRoot RCS	MTA Fillapex	-1.003300	.810	0.607 #
		Sealapex	-1.411600	.810	0.318 #
		ZOE	-4.398400*	.810	0.0005 **
	MTA Fillapex	Sealapex	-.408300	.810	0.958 #
		ZOE	-3.395100*	.810	0.001 **
	Sealapex	ZOE	-2.986800*	.810	0.004 **
# No Sig at P > 0.05 level ,** Highly Sig at P < 0.01 level					

Table 3 a – **DESCRIPTIVE STATISTICS OF GAP FORMATION BETWEEN DENTIN- SEALER INTERFACE AT THE APICAL THIRD, WITH THE DIFFERENT SEALERS USED**.

Descriptives					
APICAL	BioRoot RCS	10	2.417	1.111	.351
	MTA Fillapex	10	4.088	1.466	.464
	Sealapex	10	5.249	2.114	.669
	ZOE	10	9.970	3.663	1.158
	Total	40	5.431	3.605	.570

Table 3 b – **RESULTS OF ONEWAY-ANOVA**

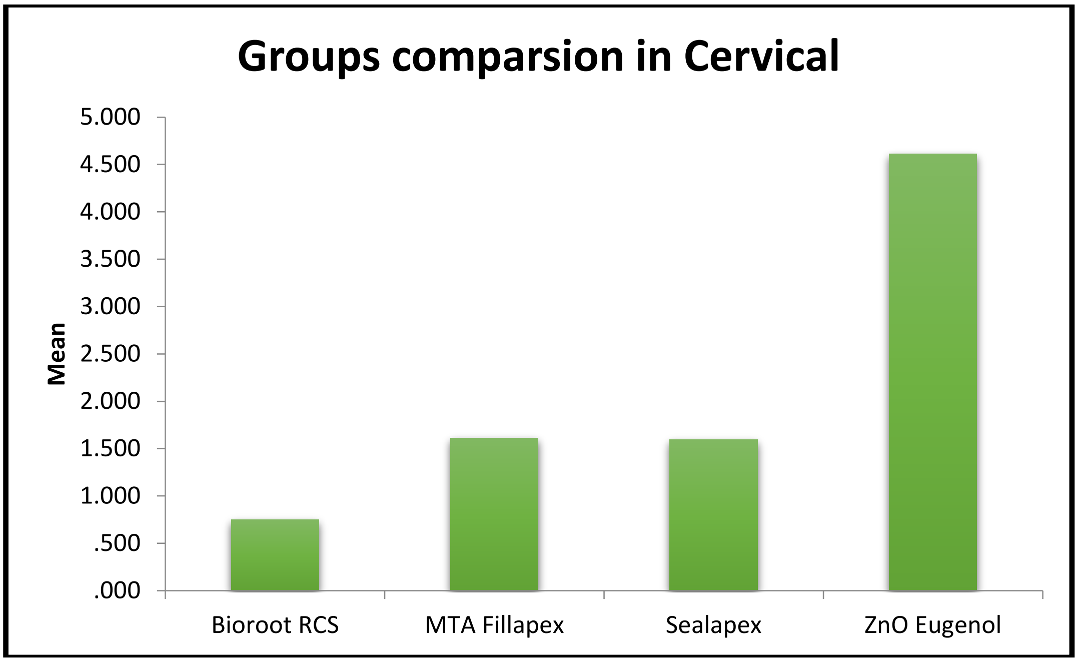
Oneway - ANOVA						
		Sum of Squares	df	Mean Square	F	P-value
APICAL	Between Groups	315.308	3	105.103	19.768	0.0005 **
	Within Groups	191.410	36	5.317		
	Total	506.718	39			
** Highly Sig at P < 0.01 level						

<u>Table 3 c</u> – PAIRWISE TESTS *POST HOC* TESTS

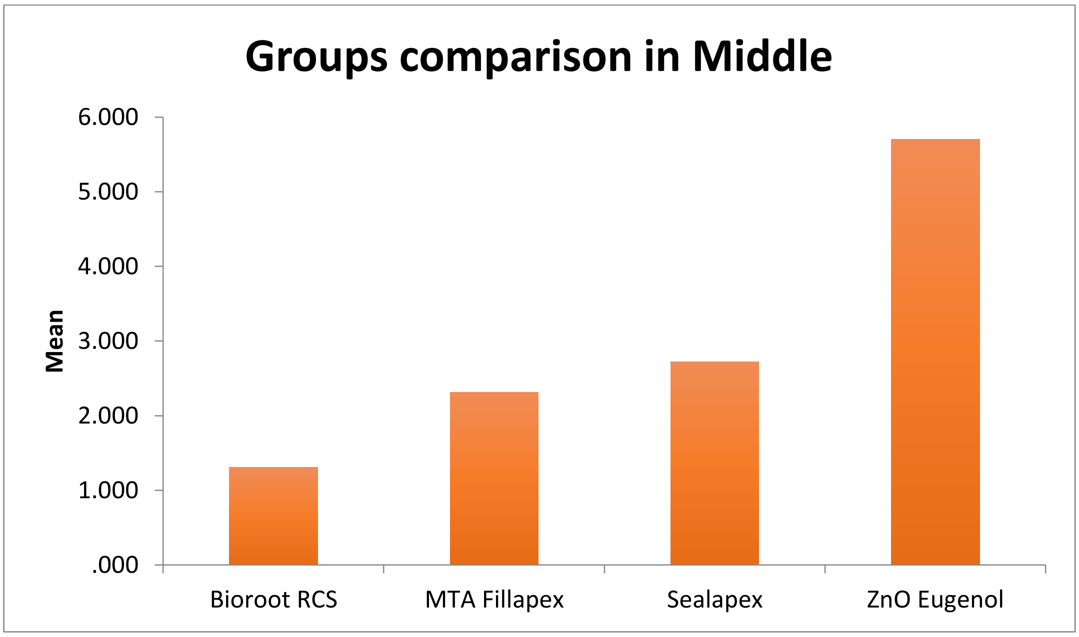
Post Hoc Tests - Multiple Comparisons - Tukey HSD					
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.
APICAL	BioRoot RCS	MTA Fillapex	-1.671300	1.031	0.380 #
		Sealapex	-2.832100*	1.031	0.044 *
		ZOE	-7.553900*	1.031	0.0005 **
	MTA Fillapex	Sealapex	-1.160800	1.031	0.676 #
		ZOE	-5.882600*	1.031	0.0005 **
	Sealapex	ZOE	-4.721800*	1.031	0.0005 **
# No Sig , * Sig at P < 0.05 level and ** Highly Sig at P < 0.01 level					

GRAPHS

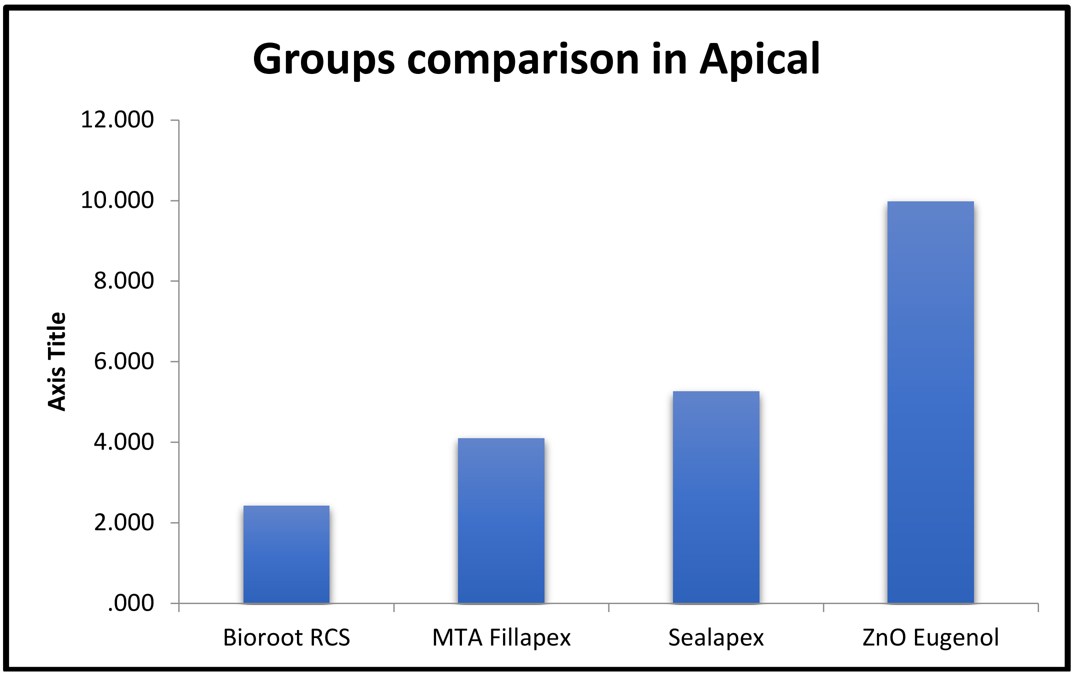
Graph 1 – GRAPH SHOWING DISTRIBUTION OF SCORES OF DIFFERENT GROUPS AT CERVICAL THIRD



Graph 2 – GRAPH SHOWING DISTRIBUTION OF SCORES OF DIFFERENT GROUPS AT MIDDLE THIRD



Graph 3 – GRAPH SHOWING DISTRIBUTION OF SCORES OF DIFFERENT GROUPS AT APICAL THIRD



Discussion

DISCUSSION

The main goal of root canal obturation is to provide a three dimensional fluid tight seal, thus preventing the chances for reinfection of the root canal and thereby preserving the health of periapical tissues. Ingle in 1956, stated that about 58% of the endodontic failures may be attributed to the incomplete obturation of the root canals.[15] Hence, various researchers have tried numerous different materials to completely obliterate this space since the early 1800's. Of these, gutta percha is the most popularly used root canal obturating material which has got acceptance for more than 100 years.[48] Obturation with Gutta–percha along with a root canal sealer is considered to be the gold standard in root canal therapy.[15]

Gutta-percha is the most popular root canal obturating material because of its advantages like biocompatibility, non-toxicity, non-allergic nature and its ease of retrieval from the root canal in cases of retreatment.[49] In spite of various advantages, it has few demerits like, inability to bond with the root canal dentin and the hydrophobic nature of gutta percha tends to make the sealer pull away from it upon setting.[28] For a hermetic seal, gutta-percha alone is not sufficient, as it has no adhesion to the root canal walls. Root canal sealers are needed to fill in the voids between the gutta-percha cones as well as those between the gutta-percha cones and root canal dentinal walls. Hence a complete hermetic sealing of the root canal seems to be difficult, even when using a combination of gutta-percha and a root canal sealer in the general clinical use.[15]

Furthermore the presence of a smear layer on the dentinal walls also reduce the dentin permeability and hinders with the penetration of the root canal sealer into the dentinal tubules.[50] The smear layer formed on the surface of the dentinal walls during root canal instrumentation is assumed to prevent the penetration of the endodontic sealers into the dentinal tubules as it occludes them. Therefore, it is believed that the smear layer can hinder with the penetration and adaptation of the root canal sealers. Dentinal tubule penetration depth is considered as the performance measure of a root canal sealer. Various studies have shown that the sealer penetration into the dentinal tubules forms a physical barrier, entombing the residual bacteria and improves retention of the root filling. However, previous studies have found no correlation between the actual sealer penetration into dentinal tubules and the sealing ability of the endodontic filling material.[51]

Biomechanical preparation is a significant step to obtain a successful endodontic treatment outcome. Shaping and cleaning of root canals are important phases in endodontic therapy. According to Schilder (1974), the clinical goal of cleaning and shaping is to satisfy the biological and mechanical objectives. Biological objective is achieved by a total debridement of the root canal. Obtaining glassy smooth walls is a preferred indicator for maximum debridement. The mechanical objective is to maintain or develop a continuously tapering funnel form with the smallest diameter at the apex and the widest diameter at the orifice.

Nickel-titanium instruments have been generally used for mechanical preparation in endodontic practice because of their relatively higher reliability and better flexibility and efficiency than stainless steel files. ProTaper Universal (PTU) which is a conventionally used NiTi rotary system was used in the study. The instrument has a variable taper along its length and a convex triangular cross- section.[49] The use of this rotary file system reduces the time required for shaping and also improves the standardization of instrumentation.[6]

However, this does not negate the importance of the quality of the obturation in which the sealer has a major role to play.[26] Several types of endodontic sealers have been recommended to achieve this goal.[2] Grossman described the ideal properties of a root canal sealer as those which, provides good adhesion between itself and the root canal wall when set; helps in establishing a hermetic seal; does not undergo shrinkage upon setting; are insoluble in tissue fluids and is tissue tolerant. The currently available commercial root canal sealers can be broadly categorized as ZOE- based, glass ionomer- based, calcium hydroxide- based, resin- based, silicone-based and the more recently introduced, calcium silicate based root canal sealers. However, at present none of the existing sealers satisfies all the above mentioned criteria. Zinc oxide eugenol- based, calcium hydroxide-based and glass ionomer- based sealers possess a problem of dissolving when in contact with periradicular tissue fluids; whereas zinc oxide eugenol- based sealer shrinks slightly when set; but recently introduced calcium silicate based materials have attracted considerable attentions because of their good biocompatibility and bioactivity.[4]

Lateral compaction is the most common root canal filling technique. As a result of the advent of NiTi rotary systems and the tapered gutta-percha cones, single- cone obturation technique has become more widespread and useful clinically.[49] Obturation with single-cone was done in the present study to simulate the most common method employed in clinical scenario and for maintaining the homogeneity among groups. The use of a single-cone obturating technique is often considered inferior to other more sophisticated, three-dimensional compaction techniques.[53] But the single cone technique was performed due to its wide use in Endodontics and because sealer penetration does not depend on the filling technique.[50]

Studies in past have evaluated the sealing ability of root canal sealers through various methods measuring microleakage, such as dye penetration, electrical methods, fluid filtration technique, radioisotope tracing and marginal adaptation by SEM.[51] In this study, a scanning electron microscope was utilized for the assessment of marginal gap between the root canal dentin and the sealer. The advantage of using SEM over other microleakage assessment methods is that in SEM, the submicron level defects can be observed at a required magnification and the final evaluation can be done by preservation of the microphotographs.[28]

Leakage studies have been widely used in the past for assessment of sealing ability of root canal sealers. However, leakage evaluations show a great degree of variations in studies and the results are often contrasting. In the present study, quality of the root canal seal was assessed through a histological method by SEM evaluation, as it has a larger depth of field, higher resolution, and better magnification at the interface which has been pointed out by Punithia and Shashikala et al.[47]

In the present study, single rooted mandibular premolars were used. Dummer et al in his study evaluated the use of extracted teeth for in-vitro studies and concluded that extracted teeth compromises the standardization of samples due to the variations in root anatomy and in dentin hardness. However, it enables SEM investigation of canal cleanliness and provides conditions close to the clinical situation.

The seal along the dentin-sealer interface and also at the gutta percha-sealer interface prevents the percolation and leakage of fluids thereby preventing reinfection. This study focuses on the comparative evaluation of marginal gap formation at the cervical, middle and apical thirds of gutta percha with BioRoot RCS, MTA Fillapex, Sealapex and ZOE at the dentin-sealer interface using SEM.

Adhesion of the root canal sealer to root dentin at the dentin- sealer interface is a basic requirement of any root canal filling material.[54] In the present study, three root canal sealers, i.e, BioRoot RCS, MTA Fillapex, Sealapex and ZOE (control group) sealers with gutta percha was used to evaluate the marginal adaptation to root dentin at the cervical, middle and apical thirds. Compared to all the experimental sealers, BioRoot RCS showed superior marginal adaptation at all the 3 levels, represented by lower gap formation, followed by MTA Fillapex and Sealapex whereas ZOE showed poor adaptation. Higher interfacial gaps were observed at the apical thirds of all the sealer types than that was observed at the coronal level. This observation was consistent with the results of previous studies.[55]

This discrepancy between the apical and coronal third levels might be accounted to the lower density and diameter of the dentinal tubules found at the apical level, thus resulting in lower sealer penetration.[28] Moreover, smear layer removal from the apical third level is difficult, that might also act as a physical barrier which interferes with the proper sealer adaptation to the root canal dentin.[56]

Among all the three tested groups in this study, the BioRoot RCS sealer was the best group which had minimal gap formation at the dentin-sealer interface. A better performance of this bioceramic sealer can be attributed to its hydrophilicity, small particle size, chemical bonding to the root canal dentin and low contact angle which enables it to easily spread over the dentin walls of the root canal and to get inside and fill the lateral micro-canals as well. It is also seen to exhibit a significant expansion of 0.20%. These features helps in the formation of a gap-free chemical bond between the sealer- dentin interface, thus, making it an effective sealer.[2]

BioRoot RCS is a hydraulic cement, that is available as a powder composed of tricalcium silicate, povidone, zirconium oxide and a water- based liquid, with additions of calcium chloride and polycarboxylate. It has been proposed initially that, this material should be used only with cold lateral compaction canal filling techniques, as the heat generated during thermoplastic obturation techniques negatively affects the flowability and film thickness of the material.[52] Recently, it was suggested that the single cone cold obturation technique could be used with the hydraulic calcium silicate cements.[57]

Tricalcium silicate-based sealers were introduced by around 1999, after the increase in popularity of mineral trioxide aggregate because of its calcium releasing ability and bioactivity.[58] The first commercial tricalcium silicate-based sealer introduced was MTA Fillapex, which was the first developed MTA based paste- paste, salicylate resin root canal sealer, that is mostly composed of a salicylate resin rather than MTA. The catalyst paste comprises of a natural resin, salicylate resin, diluting resin and bismuth oxide, while the base paste consists of MTA, nanoparticulate silica and pigments.

MTA Fillapex does not form calcium hydroxide on hydration and also exhibits low calcium ion release in solution.[5]

MTA Fillapex, is the other sealer used in this study, which showed a statistically high significant difference compared to the control group of ZOE. Sarkar *et al.*, suggested that calcium and hydroxyl ions will be released in the presence of phosphate containing fluids which will result in the formation of apatite that promotes controlled mineral nucleation on dentin which can be seen as the formation of an interface layer with tag- like structures.[59] According to a study done by Nagas *et al.*, there is better bonding of MTA Fillapex when the canals are finally rinsed with distilled water and blot dried with paper points to achieve moist condition. However in this study, MTA Fillapex displayed little or less tags depicting limited adaptation to the dentin compared to the other bioceramic sealer (BioRoot RCS) under scanning electron microscope. This may be attributed to the unpredictable moisture content in the canal. The reason for the inferior marginal adaptation of MTA Fillapex could be the low adhesion of the material due to poor microtags formed on setting.[28]

The Sealapex sealer differs from other root canal sealers in that it contains calcium hydroxide as a major constituent. This material has a very low setting shrinkage and low solubility in tissue fluids. Sealapex is a paste-paste sealer which contains calcium hydroxide in a polymeric matrix. Sealapex sealer is formulated to promote rapid healing and hard tissue formation in the clinical perspective.[18] It has been shown that this material being porous, permits marked ingress of water and promotes continued reaction between powder and binder. Cobankara FK et al., studied the apical seal of four sealers using computerized fluid filtration method. Sealapex demonstrated significantly less leakage compared to AH Plus, polymeric based and ZOE based sealers. Few other studies have reported no significant differences in apical leakage between Sealapex and AH Plus.[38] In the present study, Sealapex showed a better adaptation to the dentinal walls at the cervical third in comparison to MTA Fillapex, though at the middle and apical thirds it showed less adaptation than MTA Fillapex and a statistically high significant difference when compared to ZOE sealer.

In this study, ZOE sealer exhibited the highest gap formation compared to other sealers which is in agreement with other studies. The ZOE based sealers have shown to have poor sealing and adhesion properties to the dentin surface. Moreover, in aqueous environment, the solubility is more resulting in dissociation of zinc eugenolate in to zinc hydroxide and eugenol.[38] However it has been shown that when ZOE based sealers are placed in a totally dried canal, the leakage exhibited by the sealer was less, which corresponds to better sealing ability.[60]

This study evaluated the sealing ability of three endodontic sealers with gutta percha, to the root dentin by measuring the marginal gap formation at the sealer- dentin interface using SEM. The three different sealers used were BioRoot RCS, MTA Fillapex and Sealapex, with ZOE as the control group. The gaps formed on the sealer- dentin interface, at different levels (cervical, middle, apical) in each samples of the four experimental groups were measured from the microphotographs and then compared.

The amount of gap formation indicates the sealing ability of the material. In the present study it was found that there was a statistically significant difference in the amount of gap formation by ZOE sealer at all the 3 levels of the root canal. The mean amount of gap formation by ZOE was the highest at the apical third level, followed by the middle and cervical thirds. From evaluation of the results, it is found that ZOE sealer has the lowest sealing ability. Sealing properties of ZOE sealers were inferior in comparison to other sealers due to the relatively high solubility of the material, which makes the adhesion between gutta percha and ZOE weak.[61] The above findings are in agreement with various studies which were previously conducted (Table 1-3) (Graph 1-3).

In the current study it was also found that, BioRoot RCS showed the least amount of gap formation as compared to other experimental groups (Table 1-3) (Graph 1-3). It consists of tricalcium silicate, zirconium dioxide and povidone, water and calcium chloride. In addition, the manufacturer claims that BioRoot RCS can obturate the root canal with and even without gutta-percha cones, because of the excellent bonding by penetrating into the dentin structure.[62] These characteristics may explain the results obtained. In a previous study by Siboni F. *et al*., BioRoot RCS showed higher calcium ion release than other sealers over a prolonged duration. The prolonged mineralizing ion release triggers the nucleation of calcium phosphate, which may improve the sealing ability of obturation materials.[63] In the study of Uzunoglu-Özyürek et al., BioRoot RCS provided higher dentinal tubule penetration than AH 26, even in the presence of calcium hydroxide when all experimental groups were obturated with a single gutta- percha cone combined with one sealer.[44]

The present study also reveals that MTA Fillapex is found to create less gaps at all levels except at the cervical third, where Sealapex was found to form lesser gaps (Table 1) (Graph 1). This finding is in association with previous studies that have shown that MTA Fillapex has a high flow rate and low film thickness, which helps it to easily penetrate the accessory and lateral canals.[64] In a study by Srinidhi *et al.,* Sealapex showed less leakage compared to AH Plus, MTA plus and ZOE sealers though it was not statistically significant with MTA Plus sealer. Caicedo and Fraunhofer studied the properties of calcium hydroxide sealers and found that Sealapex showed a significant volumetric expansion during setting. They theorized that this was because of water absorption. This may also increase the solubility of Sealapex. But, an in vitro dye penetration study by Sleder et al. showed that Sealapex is no more soluble than other sealers and that its seal is comparable to TubliSeal

(ZOE-based sealer) at 32 weeks.[65] There was no significant difference in gap formation between MTA Fillapex and Sealapex groups.

Hence in this study, on comparing the three different root canal sealers, BioRoot RCS, MTA Fillapex and Sealapex, it was found that BioRoot RCS showed a better sealing ability. MTA Fillapex and Sealapex groups showed similar adaptation, of which MTA Fillapex was better. All the tested sealers showed better sealing ability than the control group of ZOE sealer.

Summary

SUMMARY

The aim of this in vitro study was to evaluate the sealing ability of three endodontic sealers, BioRoot RCS (a tricalcium silicate based sealer), MTA Fillapex (a salicylate resin based sealer) and Sealapex (a calcium hydroxide based sealer) with gutta-percha cones to the dentinal walls, using scanning electron microscopy (SEM).

In this study , 40 human mandibular premolars were used. On each premolar, access cavities were prepared and a size 10 K- file was inserted in the root canal until it was just visible at the apical foramen. The root canals were instrumented through crown-down technique with Protaper Universal rotary files until the working length. The canals were irrigated with 2ml of 5% sodium hypochlorite during instrumentation and finally rinsed with 2ml of 17% ethylenediaminetetraacetic acid for 5 minutes followed by 2ml of normal saline and then were dried with absorbent paper points. Then, the teeth were randomly divided into 4 experimental groups (Group I, II, III, IV) of 10 samples each.

In Group 1, BioRoot RCS was used to obturate the canals along with .06 taper GP. In Group 2, MTA Fillapex was used to obturate the canals along with .06 taper GP. In Group 3, Sealapex was used. Group 4 was control group with ZOE sealer. The excess GP was seared off and ZOE entrance filling was done.

After complete obturation, all root samples were kept moist by keeping them in gauze moistened with sterile saline for 1 week at 37°C to ensure complete setting of the sealer. The 40 experimental root specimens were painted with two layer of nail varnish at the coronal 1 mm and apical 2 mm. For assessment of gaps, the slices were dehydrated in an ascending ethanol series. Each root was then cross sectioned using a diamond disk on a slow speed handpiece to obtain the dentin- root canal filling interface at the cervical, middle and apical thirds of the root under water cooling spray.

All the sectioned specimens were washed in 17% EDTA solution and methanol, then blot dried, which was then gold sputtered and observed under SEM. The values obtained from the analysis were subjected to statistical analysis – One Way ANOVA and post hoc test.

Conclusion

CONCLUSION

Within the limitations of the study, it can be concluded that:

1. Minimum gap formation was seen for the bioceramic sealers, with BioRoot RCS being better than MTA Fillapex.
2. In the middle third, the calcium hydroxide based sealer, Sealapex showed better adaptation than MTA Fillapex sealer. Whereas in cervical and apical thirds, MTA Filllapex exhibited lesser gap formation than Sealapex.
3. All tested sealers showed significantly better adaptation and sealing ability at the cervical and middle thirds than the apical third compared to ZOE.
4. Bioceramic sealers showed higher penetration at the apical third.

Bibliography

BIBLIOGRAPHY

1. **Anil K Tomer, Ruchi Gupta, Midhun Ramachandran, Ashvin G John, Afnan Ajaz Raina, Akankshita Behera and Nitish Mittal**

   Comparison of the apical sealing ability of calcium hydroxide, MTA, and silicone based sealers

   International Journal of Applied Dental Sciences 2018; 4(1): 03-05

2. **Asha Pius, Jain Mathew, Robin Theruvil, Saira George, Midhun Paul, Allu Baby, John Jacob**

   Evaluation and Comparison of the Marginal Adaptation of an Epoxy, Calcium Hydroxide-based, and Bioceramic-based Root Canal Sealer to Root Dentin by SEM Analysis: An *In Vitro* Study

   Conservative Dentistry and Endodontic Journal (2019): 10.5005/jp-journals-10048-0046

3. **Yan Huang, Kaan Orhan, Berkan Celikten, Ayşe Işıl Orhan, Pelin Tufenkci, Semra Sevimay**

   Evaluation of the sealing ability of different root canal sealers: a combined SEM and micro-CT study

   J Appl Oral Sci. 2018;26:e20160584

4. **Yahui Wang, Siyi Liu, Yanmei Dong**

   In vitro study of dentinal tubule penetration and filling quality of bioceramic sealer

   PLoS ONE, 2018; 13(2): e0192248.

5. **Viapiana R, Moinzadeh AT, Camilleri L, Wesselink PR, Tanomaru Filho M, Camilleri J.**

   Porosity and sealing ability of root fillings with gutta-percha and BioRoot RCS or AH Plus sealers. Evaluation by three ex vivo methods.

   International Endodontic Journal, 2015; 12513

6. **Lovejeet Ahuja, Purshottam Jasuja, KanikaGuptaVerma, Suruchi Juneja, Aditi Mathur, Rashmeet Walia, Ashish Kakkar, Metashi Singla**

   A Comparative Evaluation of Sealing Ability of New MTA Based Sealers with Conventional Resin Based Sealer: An In-vitro Study

   Journal of Clinical and Diagnostic Research. 2016 Jul, Vol-10(7): ZC76-ZC79

7. **Piedad S. Cañadas, Ester Berástegui, Patrícia Gaton-Hernández, Léa A. B. Silva, Giselle A. Leite, Roberto S. Silva**

   Physicochemical properties and interfacial adaptation of root canal sealers

   Brazilian Dental Journal (2014) 25(5): 435-441

8. **Issam Khalil, Alfred Naaman and Josette Camilleri**

   Properties of Tricalcium Silicate Sealers

   J Endod 2016;42:1529–1535

9. **Eric J. Hovland & Thomas C. Dumsha**

   Leakage evaluation *in vitro* of the root canal sealer cement Sealapex

   International Endodontic Journal (19S5) 18,179-182

10. **Bradley H. Gettleman, Harold H. Messer and Mahmoud E. EIDeeb**

    Adhesion of Sealer Cements to Dentin with and without the Smear Layer

    Journal of Endodontics, Jan 1991, Vol. 17, No. 1

11. **Kwang-Won Lee, Michael C. Williams, Jean J. Camps and David H. Pashley**

    Adhesion of Endodontic Sealers to Dentin and Gutta-Percha

    Journal of Endodontics,Vol. 28, No. 10, October 2002

12. **Gustavo De-Deus, Eduardo Diogo Gurgel-Filho, Cláudio Maniglia-Ferreira, Tauby Coutinho-Filho**

    Influence of the filling technique on depth of tubular penetration of root canal sealer: a scanning electron microscopy study

    Braz J Oral Sci. April/June 2004 - Vol. 3 - Number 9

13. **K. Mamootil & H. H. Messer**

    Penetration of dentinal tubules by endodontic sealer cements in extracted teeth and in vivo

International Endodontic Journal, 2007; 1365-2591.2007.01307.x

14. **Norberto Batista de Faria-Júnior, Santiago Massi, Hugo Ricardo Croti, José Carlos Rivas Gutierrez, Fábio Roberto Dametto, Luis Geraldo Vaz**

    Comparative assessment of the flow rate of root canal sealers

    Rev. odonto ciênc. 2010;25(2)

15. **Mirjana Vujašković, Nevenka Teodorović**

    Analysis of Sealing Ability of Root Canal Sealers Using Scanning Electronic Microscopy Technique

    Srp Arh Celok Lek. 2010;138(11-12)

16. **Seyda Ersahan and Cumhur Aydin**

    Dislocation Resistance of iRoot SP, a Calcium Silicate–based Sealer, from Radicular Dentine

    JOE — Volume 36, Number 12, December 2010

17. **Bruno Carvalho De Vasconcelos, Ricardo Affonso Bernardes, Marco Antonio Húngaro Duarte, Clóvis Monteiro Bramante, Ivaldo Gomes De Moraes**

    Apical sealing of root canal fillings performed with five different endodontic sealers: analysis by fluid filtration

    J Appl Oral Sci. 2011;19(4):324-8

18. **João Eduardo Gomes-Filho, Jaqueline Viana Moreira,Simone Watanabe, Carolina Simonetti Lodi, Luciano Tavares Angelo Cintra, Eloi Dezan Junior, Pedro Felício Estrada Bernabé, Mauro Juvenal Nery, José Arlindo Otoboni Filho**

    Sealability of MTA and calcium hydroxide containing sealers

    J Appl Oral Sci. 2012;20(3):347-51

19. **Eric Balguerie, Lucas van der Sluis, Karen Vallaeys, Marie Gurgel-Georgelin and Franck Diemer**

    Sealer Penetration and Adaptation in the Dentinal Tubules: A Scanning Electron Microscopic Study

    JOE — Volume 37, Number 11, November 2011

20. **Seyda Ersahan & Cumhur Aydin**

    Solubility and apical sealing characteristics of a new calcium silicate based root canal sealer in comparison to calcium hydroxide, methacrylate resin and epoxy resin-based sealers

    Acta Odontologica Scandinavica; DOI:10.3109/00016357.2012.734410

21. **I.S. Sönmez, A.A. Oba, D. Sönmez, M.E. Almaz**

    In vıtro evaluatıon of apıcal mıcroleakage of a new MTA-based sealer

    European Archives of Paediatric Dentistry 13 (Issue 5). 2012

22. **Narasimiah Suresh Kumar, Ajitha Palanivelu, L Lakshmi Narayanan**
Evaluation of the apical sealing ability and adaptation to the dentin of two resin-based Sealers: An in vitro study
Journal of Conservative Dentistry , Sep-Oct 2013, Vol 16, Issue 5

23. **Daniela Kok, Ricardo Abreu Da Rosa, Mirela Sangoi Barreto, Fernanda Hoffmann Busanello, Manuela Favarin Santini, Jefferson Ricardo Pereira and Marcus Vin_Icius Reis SO**
Penetrability of AH Plus and MTA Fillapex After Endodontic Treatment and Retreatment: A Confocal Laser Scanning Microscopy Study
Microscopy research and technique 77:467–471 (2014)

24. **Vikram Shetty, Prashant Hegde, Rashmi Singh Chauhan, Vishwajit Rampratap Chaurasia, Akanksha Manmohan Sharma, M Taranath**
A Spectro Photometric Comparative Evaluation of Apical Sealing Ability of Three Different Sealers; Calcium Hydroxide Based, Resin Based and Zinc Oxide Eugenol Based Sealers
Journal of International Oral Health 2015; 7(2):25-27

25. **Mohammed Abdul Khader**
An *In Vitro* Scanning Electron Microscopy Study to Evaluate the Dentinal Tubular Penetration Depth of Three Root Canal Sealers
Journal of International Oral Health 2016; 8(2):191-194

26. **Alexander Pompermayer Jardine & Ricardo Abreu da Rosa1 & Manuela Favarin Santini & Márcia Wagner1 & Marcus Vinícius Reis Só & Milton Carlos Kuga & Jefferson Ricardo Pereira & Patrícia Maria Poli Kopper**

The effect of final irrigation on the penetrability of an epoxy resin-based sealer into dentinal tubules: a confocal microscopy study

Clin Oral Invest; DOI 10.1007/s00784-015-1474-8

27. **Levent Demiriz, Mustafa Murat Koçak, Sibel Koçak, Baran Can Sağlam, Sevinç Aktemur Türker**

Evaluation of the dentinal wall adaptation ability of MTA Fillapex using stereo electron microscope

J Conserv Dent 2016;19:220-4.

28. **Swapnika Polineni, Nagesh Bolla, Pragna Mandava, Sayesh Vemuri, Madhusudana Mallela, Vijaya Madhuri Gandham**

Marginal adaptation of newer root canal sealers to dentin: A SEM study

J Conserv Dent 2016;19:360-3.

29. **Rabab A. Gad, Ali M. Farag, Hatem A. El‑ Hediny, Abeer M. Darrag**

Sealing ability and obturation quality of root canals filled with gutta-percha and two different sealers

Tanta Dental Journal, 2016; DOI: 10.4103/1687-8574.195703

30. **Widcha Asawaworarit, Prapaporn Yachor, Kanittha Kijsamanmith, Noppakun Vongsavan**

Comparison of the Apical Sealing Ability of Calcium Silicate-Based Sealer and Resin-Based Sealer Using the Fluid-Filtration Technique

Med Princ Pract 2016;25:561–565

31. **Anisha Kumar, A. R. Vivekananda Pai**

Comparative assessment of the area of sealer voids in single cone obturation done with mineral trioxide aggregate, epoxy resin, and zinc-oxide eugenol based sealers

Saudi Endod J 2016;6:61-5.

32. **R. Krug & G. Krastl & M. Jahreis**

Technical quality of a matching-taper single-cone filling technique following rotary instrumentation compared with lateral compaction after manual preparation: a retrospective study

Clin Oral Invest; DOI 10.1007/s00784-016-1931-z

33. **Vimal Remy, Vineesh Krishnan, Tisson V Job, Madhavankutty S Ravisankar, CV Renjith Raj, Seena John**

Assessment of Marginal Adaptation and Sealing Ability of Root Canal Sealers: An *in vitro* Study

J Contemp Dent Pract 2017;18(12):1130-1134.

34. **F. Siboni , P. Taddei, F. Zamparini1, C. Prati & M. G. Gandolfi**

Properties of BioRoot RCS, a tricalcium silicate endodontic sealer modified with povidone and polycarboxylate

International Endodontic Journal, 50, e120–e136, 2017

35. **Haridas Das Adhikari, Sakshi Jain**

Scanning electron microscopic evaluation of marginal adaptation of AH--Plus, GuttaFlow and RealSeal at apical one-third of root canals – Part II: Core-sealer interface

J Conserv Dent 2018;21:90-4.

36. **Alessandra Timponi Goes Cruz, Fabiana Soares Grecca, Lucila Piasecki, Caroline Wichnieski, Vânia Portela Dietzel Westphalen, Everdan Carneiro, Luiz Fernando Fariniuk, Ulisses Xavier Da Silva Neto**

Influence of the Calcium Hydroxide Intracanal Dressing on Dentinal Tubule Penetration of Two Root Canal Sealers

Eur Endod J (2017) 2:14.

37. **Claudio Poggio, Paolo Riva, Marco Chiesa, Marco Colombo, Giampiero Pietrocola**

Comparative cytotoxicity evaluation of eight root canal sealers

J Clin Exp Dent. (2017), doi:10.4317/jced.53724

38. **Srinidhi V. Ballullaya, Vusurumarthi Vinay, Jayaprakash Thumu, Srihari Devalla, Indira Priyadarshini Bollu, Sagarika Balla**

    Stereomicroscopic Dye Leakage Measurement of Six Different Root Canal Sealers

    Journal of Clinical and Diagnostic Research. 2017 Jun, Vol-11(6): ZC65-ZC68

39. **Farnaz Jafari, Sanaz Jafari**

    Composition and physicochemical properties of calcium silicate based sealers: A review article

    J Clin Exp Dent. 2017;9(10):e1249-55.

40. **Attur KM, Kamat S, Shylaja KA, Tegginmani V, Patil D, Choudary RP**

    A comparison of apical seal and tubular penetration of mineraltrioxide aggregate, zinc oxide eugenol, and AH26 as root canal sealers in laterally condensed gutta-percha obturation: An in vitro study

    Endodontology 2017;29:20-5.

41. **Sampath Kumar Arikatla, Uma Chalasani, Jyothi Mandava, Rajiv Kumar Yelisela**

    Interfacial adaptation and penetration depth of bioceramic endodontic sealers

    J Conserv Dent 2018;21:373-7.

42. **Fabricio Guerrero, Esther Berástegui, Karla Aspiazu**

Porosity analysis of mineral trioxide aggregate Fillapex and BioRoot cements for use in endodontics using microcomputed tomography

J Conserv Dent 2018;21:491-4.

43. **Halenur Altan, Zeynep Göztaş, Gülsüm İnci, Gül Tosun**

Comparative evaluation of apical sealing ability of different root canal sealers

Eur Oral Res 2018; 52(3): 117-21

44. **Emel Uzunoglu-€Ozy€urek, €Ozge Erdogan and Sevinc¸ Aktemur T€urker**

Effect of Calcium Hydroxide Dressing on the Dentinal Tubule Penetration of 2 Different Root Canal Sealers: A Confocal Laser Scanning Microscopic Study

JOE; joen. 2018.02.016

45. **Gabriela Gonçalez Piai, Marco Antônio Húngaro Duarte, Angela Longo do Nascimento, Ricardo Abreu da Rosa, Marcus Vinícius Reis Só, Rodrigo Ricci Vivan**

Penetrability of a new endodontic sealer: A confocal laser scanning microscopy evaluation

Microsc Res Tech. 2018;1–4.

46. **Kaveri Baruah, Nitin Mirdha, Bobbin Gill, Nirmala Bishnoi, Tarun Gupta, Queentaj Baruah**

Comparative Study of the Effect on Apical Sealability with Different Levels of Remaining Gutta-Percha in Teeth Prepared to Receive Posts: An *in vitro* Study

Contemp Clin Dent 2018;9:S261-5.

47. **Sakshi Jain, Haridas Das Adhikari**

Scanning electron microscopic evaluation of marginal adaptation of AH-plus, GuttaFlow, and RealSeal at apical one-third of root canals – Part I: Dentin-sealer interface

J Conserv Dent 2018;21:85-9.

48. **Selen İnce Yusufoglu, Melek Akman, Makbule Bilge Akbulut, Ayce Ünverdi Eldeniz**

Fracture resistance of roots enlarged with various rotary systems and obturated with different sealers

J Dent Res Dent Clin Dent Prospect 2019; 13(3):215-220|doi: 10.15171/joddd.2019.033.

49. **Saulius Drukteinis, Vytaute Peciuliene, Hagay Shemesh, Paulius Tusas and Ruta Bendinskaite**

Porosity Distribution in Apically Perforated Curved Root Canals Filled with Two Different Calcium Silicate Based Materials and Techniques: A Micro-Computed Tomography Study

Materials 2019, 12, 1729; doi:10.3390/ma12111729

50. **Rajput J, Jain R , Pathak A**

An evaluation of sealing ability of endodontic Materials as Root Canal Sealers.

J Indian Sot Pedo Prev Dent March (2004) 22 (1)

51. **Morvarid Zafar, Maryam Iravani, Mohammad Jafar Eghbal, Saeed Asgary**

Coronal and apical sealing ability of a new endodontic cement

Iranian Endodontic Journal 2009;4(1):15-19

52. **Sevinç Aktemur Türker, Emel Uzunoĝlu, Nuhan Purali**

Evaluation of dentinal tubule penetration depth and push-out bond strength of AH 26, BioRoot RCS, and MTA Plus root canal sealers in presence or absence of smear layer

J Dent Res Dent Clin Dent Prospect 2018; 12(4):294-298| doi: 10.15171/joddd.2018.046

53. **E . G . Kontakiotis, M-K. Wu & P.R. Wesselink 54**

Effect of sealer thickness on long-term sealing ability: a 2-year follow-up study

International Endodontic Journal (1997) 30, 307–312

54. **João Vicente Baroni Barbizam, Martin Trope, Mario Tanomaru-Filho, Erica Cappelletto Nogueira Teixeira, Fabricio Batista Teixeira**

Bond strength of different endodontic sealers to dentin: push-out test

J Appl Oral Sci. 2011;19(6):644-7

55. **Afaf AL-HADDAD, Noor Hayaty ABU KASIM and Zeti Adura CHE AB AZIZ**

Interfacial adaptation and thickness of bioceramic-based root canal sealers

Dental Materials Journal 2015; 34(4): 516–521

56. **D. R. Violich & N. P. Chandler**

The smear layer in endodontics – a review

International Endodontic Journal, 43, 2–15, 2010

57. **Ji Wook Jeong, Anna DeGraft-Johnson, Samuel O. and Peter M. Di Fiore**

Dentinal Tubule Penetration of a Calcium Silicate–based Root Canal Sealer with Different Obturation Methods

JOE, joen. 2016.11.023

58. **N. K. Sarkar, R. Caicedo, P. Ritwik, R. Moiseyeva, and I. Kawashima**

Physicochemical Basis of the Biologic Properties of Mineral Trioxide Aggregate

JOE - Volume 31, Number 2, February 2005

59. **Shalin Desai and Nicholas Chandler**

Calcium Hydroxide–Based Root Canal Sealers: A Review

JOE; doi:10.1016/j.joen.2008.11.026

60. **Noriyasu Hosoya, Mariko Nomura, Akiko Yoshikubo, Takashi Arai, Jiro Nakamura and Charles F. Cox**

Effect of Canal Drying Methods on the Apical Seal

JOE; Vol. 26, No. 5, May 2000

61. **Manjusha Rawtiya, Kavita Verma, Shweta Singh, Swapna Munuga, Sheeba Khan**

MTA based root canal sealers

Jpjournals- 10026-1057

62. **Selen İnce Yusufoglu1, Melek Akman, Makbule Bilge Akbulut, Ayce Ünverdi Eldeniz**

Fracture resistance of roots enlarged with various rotary systems and obturated with different sealers

JODDD, Vol. 13, No. 3 Summer 2019

63. **Yemi Kim, Ban-Suk Kim , Yong-Min Kim, Donghee Lee and Sin-Young Kim**

The Penetration Ability of Calcium Silicate Root Canal Sealers into Dentinal Tubules Compared to Conventional Resin-Based Sealer: A Confocal Laser Scanning Microscopy Study

Materials 2019, 12, 531; doi:10.3390/ma12030531

64. **Sanjeev Tyagi, Priyesh Mishra, Parimala Tyagi**

Evolution of root canal sealers: An insight story

European journal of general dentistry, 10.4103/2278-9626.115976

65. **Funda Kont Cobankara, Hasan Orucoglu, Abdülkadir Sengun and Sema Belli**

The Quantitative Evaluation of Apical Sealing of Four Endodontic Sealers

J Endod 2006;32:66–68

Annexures

ANNEXURE –I

RAGAS DENTAL COLLEGE & HOSPITAL
(Unit of Ragas Educational Society)
Reconized by the Dental Council of India, New Delhi
Affiliated to The Tamilnadu Dr. M.G.R. Medical University, Chennai
2/102, East Coast Road, Uthandi, Chennai - 600 119. INDIA
Tele : (044) 24530002, 24530003 - 06. Principal (Dir) 24530001 Fax : (044) 24530009

TO WHOM SO EVER IT MAY CONCERN

Date: 24th January, 2020

Place: Chennai

From
The Institutional Review Board,
Ragas Dental College And Hospital,
Uthandi,
Chennai- 119

The project titled "Evaluation of the sealing ability of Gutta-percha with Bioroot RCS, MTA Fillapex and Sealapex – An SEM study" submitted by **Dr. Anitha Varghese** has been approved by the Institutional Review Board of Ragas Dental College And Hospital.

DR. N.S.AZHAGARASAN, MDS
Member secretary,
The Institutional Review Board
Ragas Dental College And Hospital
Uthandi,
Chennai-119

ANNEXURE –II

URKUND

Urkund Analysis Result

Analysed Document: Anitha Varghese.docx (D63045770)
Submitted: 1/27/2020 1:30:00 PM
Submitted By: anitha.vt@gmail.com
Significance: 5 %