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Comparison of Sealing Ability of Five Different Root Canal Sealers When Calcium Hydroxide is Used as Intracanal Medicament: A Sem Study

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ABSTRACT

INTRODUCTION

Calcium hydroxide is widely used as intracanal medicament. However calcium hydroxide is very difficult to remove completely from the root canal.This may cause pooradaptation of root canal filling material to canal wall leading to microleakage and subsequently failure of root canal treatment.

The purpose of this in-vitro study is to compare the sealing ability of five different sealers when calcium hydroxide is used as an intracanal medicament.

METHODOLOGY- 50 extracted teeth with single root canal anatomy will be selected.The teeth were kept to a standardized length of 16mm from the apex. Access cavities were prepared and canals were prepared upto working length to size 40 with K-files by step back technique. Calcium hydroxide was placed as an intracanal medicament. Access cavities were sealed with temporary cement and incubated for 7 days at 37ºC.Following the removal of dressing after 7 days, teeth were divided into five groups of ten samples each based on the sealer used.

Group 1-Zinc oxide eugenol based sealer should be used for obturation.

Group 2- Resin based sealer

Group 3- Calcium hydroxide based sealer

Group 4- MTA based sealer.

Group 5- Bioceramic based sealer

The canals were obturated with guttapercha using lateral compaction technique. After that the roots were sectioned and examined under scanning electron microscope to check the gap at interface of dentin and sealer.

From the results of the present in vitro study **"Comparison of Sealing Ability of Five Different Root Canal Sealers When Calcium Hydroxide is Used as An Intracanal Medicament: A SEM Study" following conclusions can be drawn:-**

1. All the sealers used in this study i.e. Tubliseal EWT, AH Plus, Sealapex, MTA Fillapex, Endosequence BC showed gap at interface of dentin and sealer when calcium hydroxide is used as an intracanal medicament.
2. MTA Fillapex (MTA based root canal sealer) showed minimum gap at interface of dentin and sealer and maximum gap was showed by Tubli-Seal EWT (Zinc Oxide Eugenol based sealer).
3. Thus, MTA Fillapex (MTA based root canal sealer) can be recommended as sealer for obturation when Calcium Hydroxide is used as an intra-canal medicament.

AIMS AND OBJECTIVE

The aim of the present study was to compare the sealing ability of five different root canal sealers i.e. Zinc oxide eugenol based sealer, Resin based sealer, Calcium hydroxide based sealer, MTA based sealer and Bioceramic based sealer when calcium hydroxide is used as an intracanal medicament.

INTRODUCTION

The main aim of the root canal treatment is to eliminate bacteria from the root canal system and to prevent reinfection. The crux of endodontics revolves around the efficient preparation, complete disinfection and three dimensional obturation of the root canal.[2] The main etiology of periapical pathosis is bacterial invasion via infected root canals resulting from the progression of pulpal inflammation.[56] Mechanical preparation does not completely eliminate bacteria from dentinal tubules and other irregularities in the root canal. Therefore, the remaining microorganisms can multiply between the appointments. Hence, the placement of effective intracanal medicament is required to completely eliminate micro-organisms from the root canal system.[56]

Calcium hydroxide is presently considered as an intracanal medicament of choice. It was introduced in dentistry by Hermann in 1920. Calcium hydroxide is a white, odourless powder with high pH of 12.5 to 12.8. Its effectiveness as an intracanal medicament is due to its antimicrobial effect, anti-inflammatory property and osteogenic potential.[2]

Calcium hydroxide when used as an intracanal medicament should be completely removed from the root canal to obtain a fluid tight seal of the permanent root canal filling material. However calcium hydroxide is very difficult to remove completely from the root canal which may lead to poor adaptation of root canal filling material to canal wall leading to microleakage and failure of root canal treatment.[58]The removal of Calcium Hydroxide is accomplished through several irrigation regimens in conjunction with different instrumentation techniques. Calcium Hydroxide is usually removed from the root canals with master apical file (MAF) and copious irrigation with EDTA, NaOCl or combination of both.[90]

A variety of endodontic sealers are available commercially based on their chemical composition. There are sealers based on zinc oxide and eugenol, epoxy resin, calcium hydroxide and glass ionomer.[6]

Zinc-oxide eugenol based sealers have been traditionally the most commonly employed sealers during root canal treatment, but their irritation potential, cytotoxicity and solubility in oral fluids is also well known.[33]

Calcium hydroxide based sealers have been suggested as a replacement for traditional zinc oxide based sealers because calcium hydroxide based sealers exhibit antimicrobial activity, osteogenic as well as cementogenic potential but the need for calcium hydroxide based sealers to be soluble in order to liberate hydroxyl ions could probably imply a deficiency in their sealing ability over an extended period of time.[85]
Epoxy resin based sealers have advantage over calcium hydroxide based sealers because of their low solubility. These are used in the endodontic practice because of their favourable characteristics such as adhesion to tooth structure, long working time, ease of mixing and good sealing ability. Epoxy resin sealer AH Plus has been introduced which is claimed to be less cytotoxic, less mutagenic and more biocompatible than AH26.[33]

Glass ionomer based root canal sealers were introduced in root canal treatment because of their adhesion to dental hard tissues.[5]These sealers bond chemically to dentin of the root canal walls and gives an added advantage of preventing percolation at the sealer dentin interface. These sealers are biocompatible and are resistant to resorption by tissue fluids.[15]

MTA based sealer (MTA Fillapex) has been developed by Torabinejad. Some of the excellent properties of this sealer include dimensional stability, long term sealing capacity and high radiopacity. It promotes the deposition of hard tissue at the root apex and perforation sites. However, it shows low expansion during setting, low solubility in contact with tissue fluids and excellent viscosity for insertion. Furthermore, this eugenol-free material neither stain tooth nor interfere with adhesive procedures inside the root canal.[76]

Bioceramic based root canal sealer, (iRoot SP) is an insoluble, radiopaque, aluminum-free material that requires the presence of water to set and harden. Bioceramic sealer being biocompatible and hydrophilic in nature, expands on setting forming a ‘self seal’. It forms hydroxyapatite during the setting process and ultimately create a chemical bond between dentinal wall and the sealer. It also exhibits potent antimicrobial action, excellent biocompatibility, significant stimulation of periodontal regeneration and is osteoconductive.[81]

Different methods are available to evaluate the sealing ability of sealers, tracers like dyes, radioisotopes, bacteria and their products, such as endotoxins and other methodologies like fluid filtration and dye extraction method, scanning electron microscope etc. have been used. Scanning Electron Microscope has been used in this study as it gives a three dimensional picture of a surface being scanned along with the added advantage of having a wide range of magnification and a greater depth of focus.

The aim of this study was to compare sealing ability of five different root canal sealers – Calcium hydroxide based sealer, Zinc oxide-eugenol based sealer, Silicon based sealer, MTA based root canal sealer and Bioceramic based root canal sealer when calcium hydroxide is used as an intracanal medicament.

MATERIALS AND METHOD

The present in vitro study **"Comparison of Sealing Ability of Five Different Root Canal Sealers When Calcium Hydroxide is Used as An Intracanal Medicament : A SEM Study"**

ARMAMENTARIUM USED IN THE STUDY (PHOTOGRAPH 1)

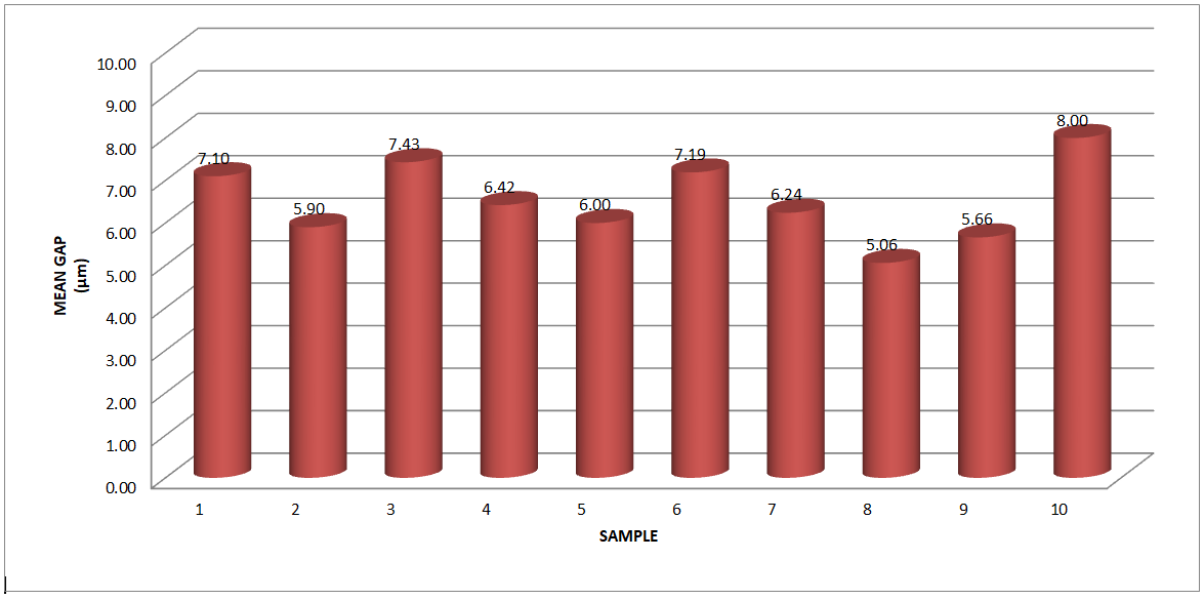
1. Airotar handpiece (NSK, Japan)
2. Contra-angle micromotor handpiece (NSK,Japan)
3. Diamond disc
4. K-files (10), (15-40), (45-80) (Mani. Inc., Japan)
5. Spreaders (15-40) (Mani. Inc., Japan)
6. Glass slab
7. Bard Parker Handle
8. Bard Parker blade No. 15
9. Stainless steel spatula
10. Mixing pad
11. Incubator **(Photograph 15)**
12. Scanning electron microscope **(Photograph 17)**

MATERIALS USED IN THE STUDY (PHOTOGRAPH 2)

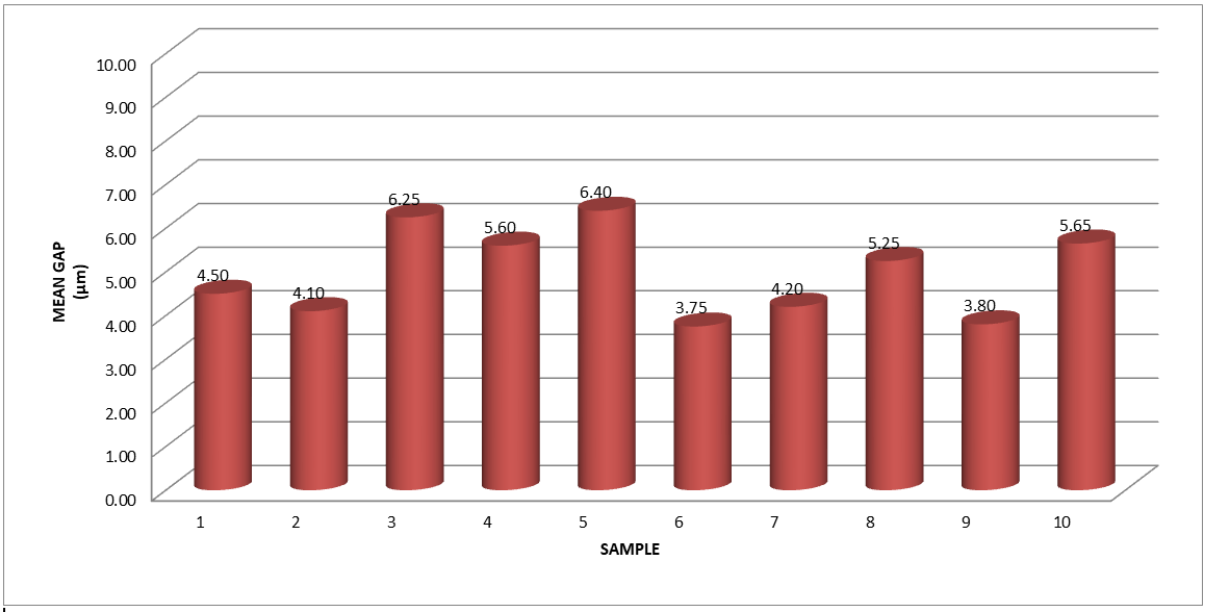
1. Gutta percha points (0.02 taper) (No. 15-40) (Dentsply Maillefer)
2. Absorbent paper points (0.02 taper) (No. 40) (EndoFirst)
3. Sodium hypochlorite solution (5% Hyposol) (Prevest DenPro)
4. AvuePrep^{+} [17% Aqueous Ethylene diamine tetraacetic acid liquid (Dental Avenue)]
5. 0.9% normal saline solution (Ives Drugs Pvt. Ltd.)
6. AvueCal (Calcium Hydroxide Paste) (Dental Avenue)
7. Coltosol F-Temporary filling material(Coltene Whaledent)

SEALERS TESTED IN THE STUDY (PHOTOGRAPH 3)

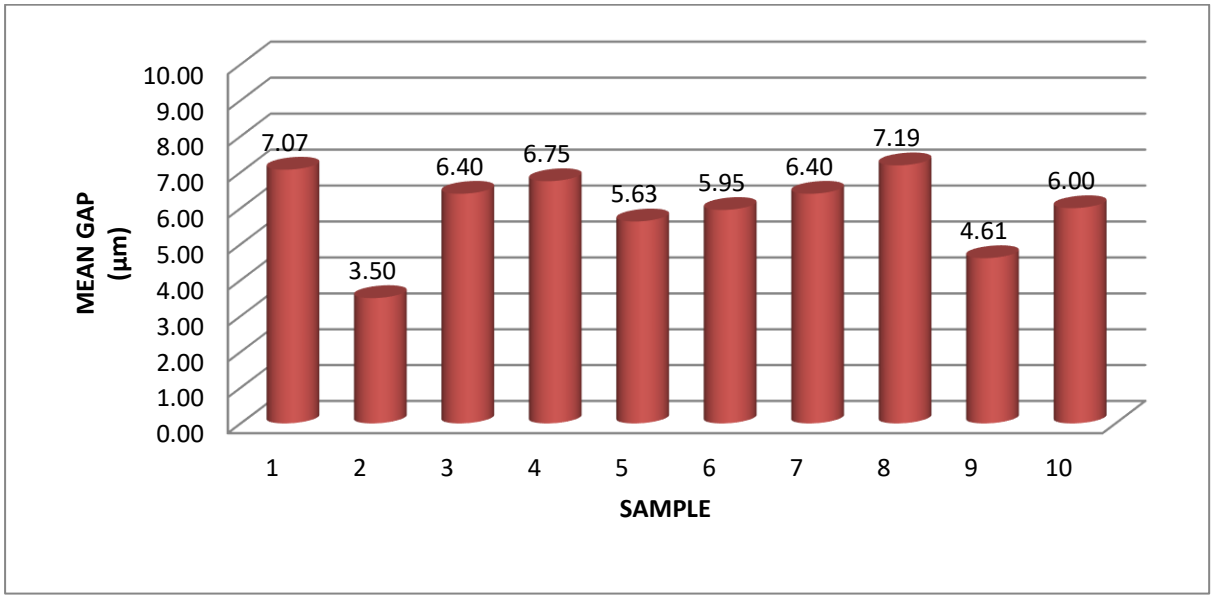
1. Sealapex Root Canal Sealer (SybronEndo)
2. Tubli-Seal EWT Root Canal Sealer (SybronEndo)
3. AH Plus Sealer (Dentsply Maillefer)
4. EndoSequence BC Sealer (Brasseler, USA)
5. MTA- Fillapex Sealer (Angelus)



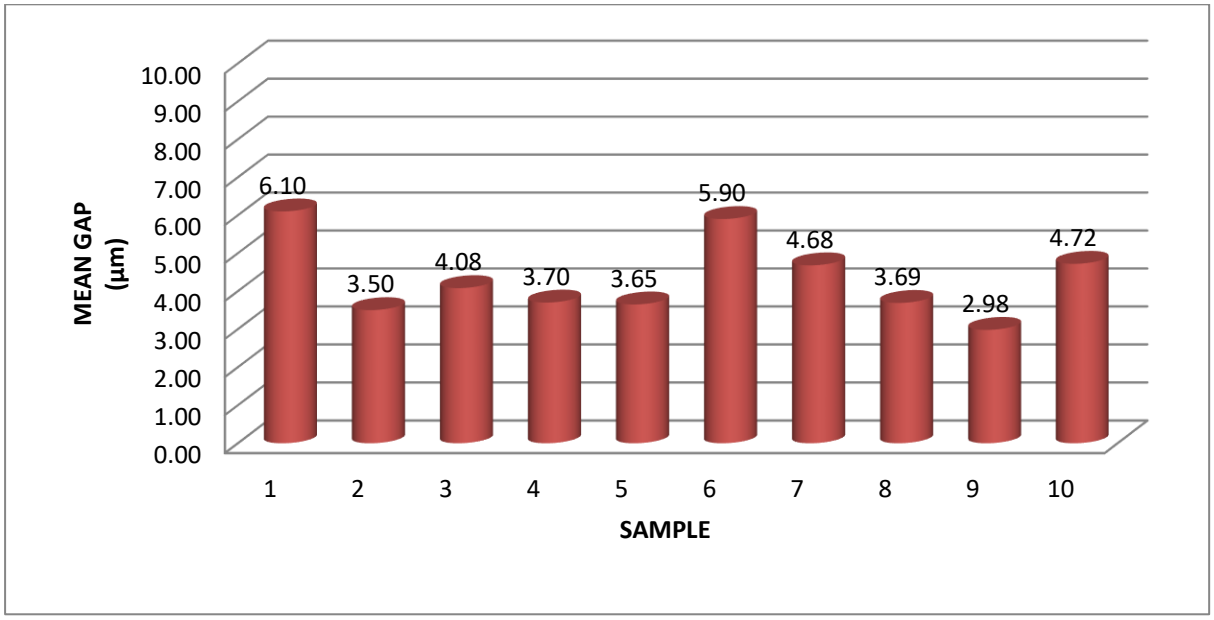
GRAPH 1- SHOWING THE MEAN GAP AT INTERFACE OF DENTIN AND SEALER (IN MICROMETERS) IN EACH SAMPLE WHEN ZINC OXIDE EUGENOL BASED SEALER (TUBLI-SEAL EWT) WAS USED



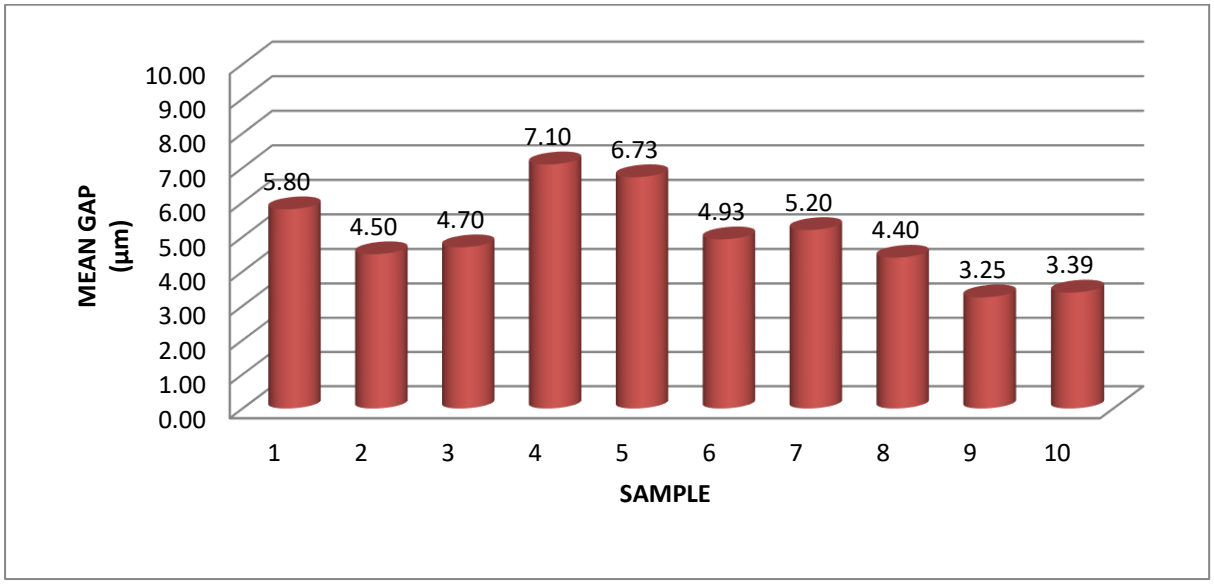
GRAPH 2- SHOWING THE MEAN GAP AT INTERFACE OF DENTIN AND SEALER (IN MICROMETERS) IN EACH SAMPLE WHEN RESIN BASED SEALER (AH PLUS) WAS USED



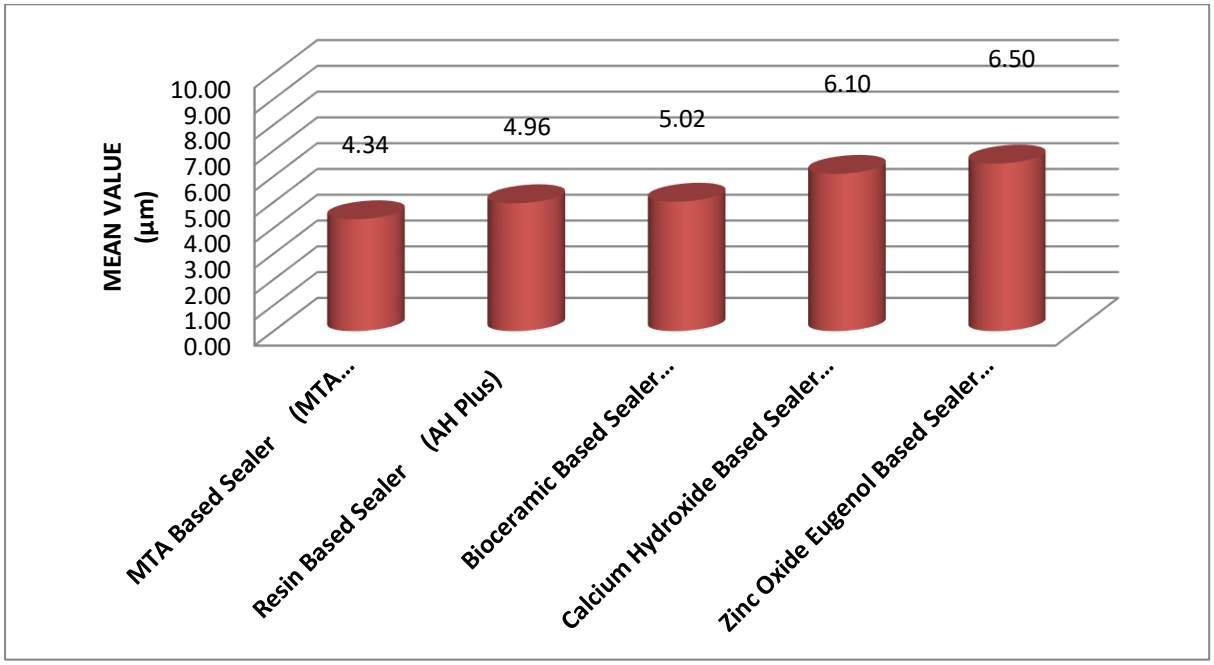
GRAPH 3- SHOWING THE MEAN GAP AT INTERFACE OF DENTIN AND SEALER (IN MICROMETERS) IN EACH SAMPLE WHEN CALCIUM HYDROXIDE BASED SEALER (SEALAPEX) WAS USED



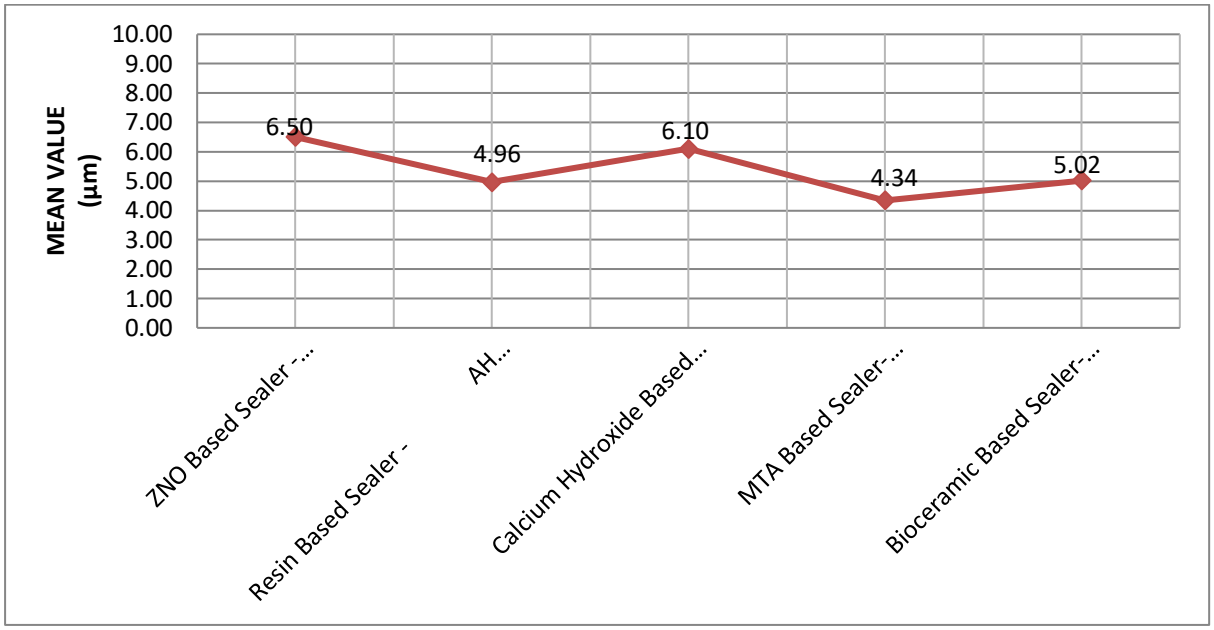
GRAPH 4- SHOWING THE MEAN GAP AT INTERFACE OF DENTIN AND SEALER (IN MICROMETERS) IN EACH SAMPLE WHEN MTA BASED SEALER (MTA FILLAPEX) WAS USED



GRAPH 5- SHOWING THE MEAN GAP AT INTERFACE OF DENTIN AND SEALER (IN MICROMETERS) IN EACH SAMPLE WHEN BIOCERAMIC BASED SEALER (ENDOSEQUENCE BC) WAS USED



GRAPH 6- SHOWING OVERALL MEAN GAP AT INTERFACE OF DENTIN AND ALL SEALERS IN MICROMETERS (µm)



LINE DIAGRAM SHOWING OVERALL MEAN GAP AT INTERFACE OF DENTIN AND ALL SEALERS IN MICROMETERS (µm)

PHOTOGRAPH 1

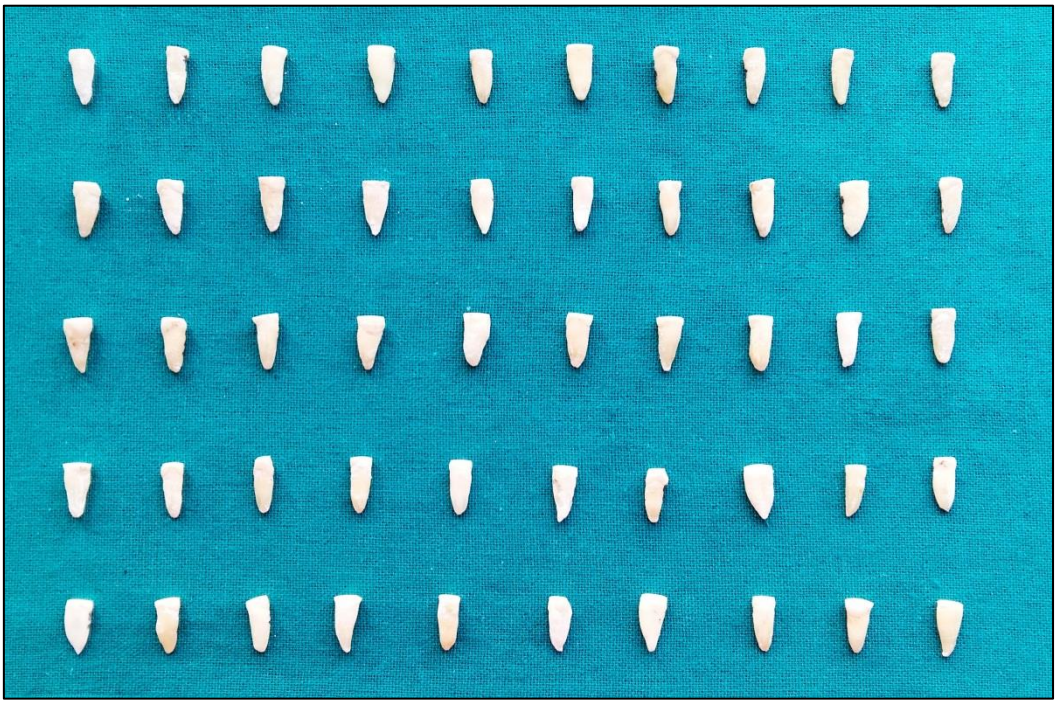
ARMAMENTARIUM USED IN THE STUDY

PHOTOGRAPH 2

MATERIALS USED IN THE STUDY

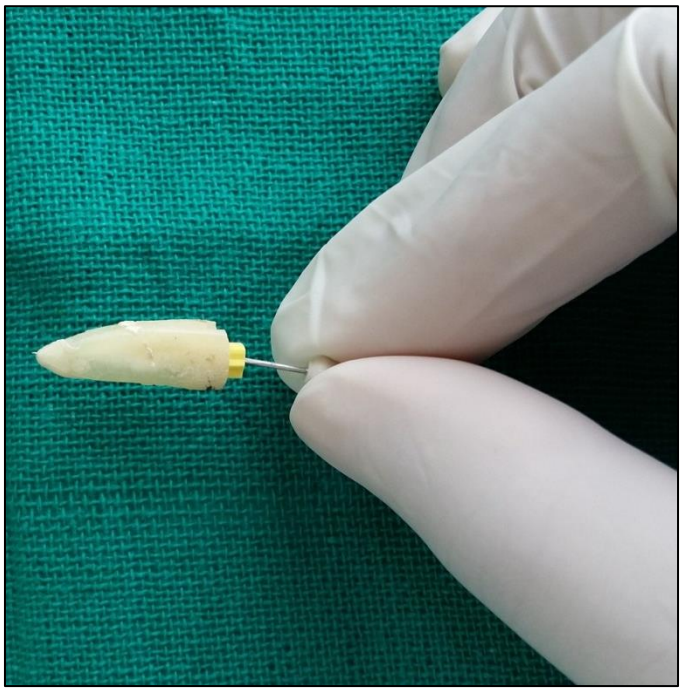
PHOTOGRAPH 3

SEALERS USED IN THE STUDY



PHOTOGRAPH 4

SAMPLES AFTER DECORONATION

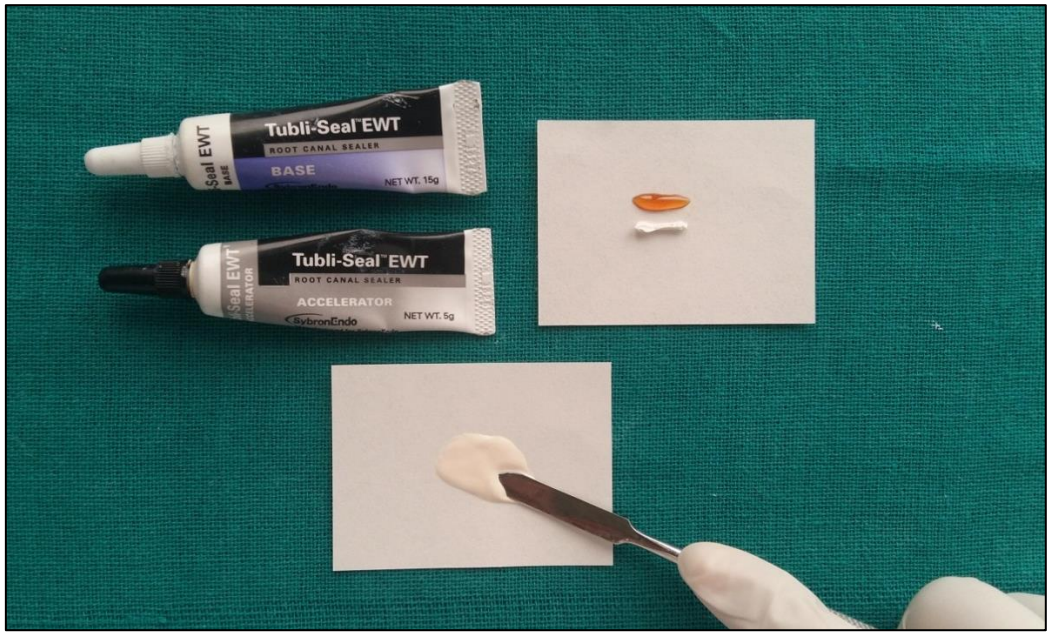


PHOTOGRAPH 5

WORKING LENGTH DETERMINATION

PHOTOGRAPH 6

PLACEMENT OF CALCIUM HYDROXIDE PASTE

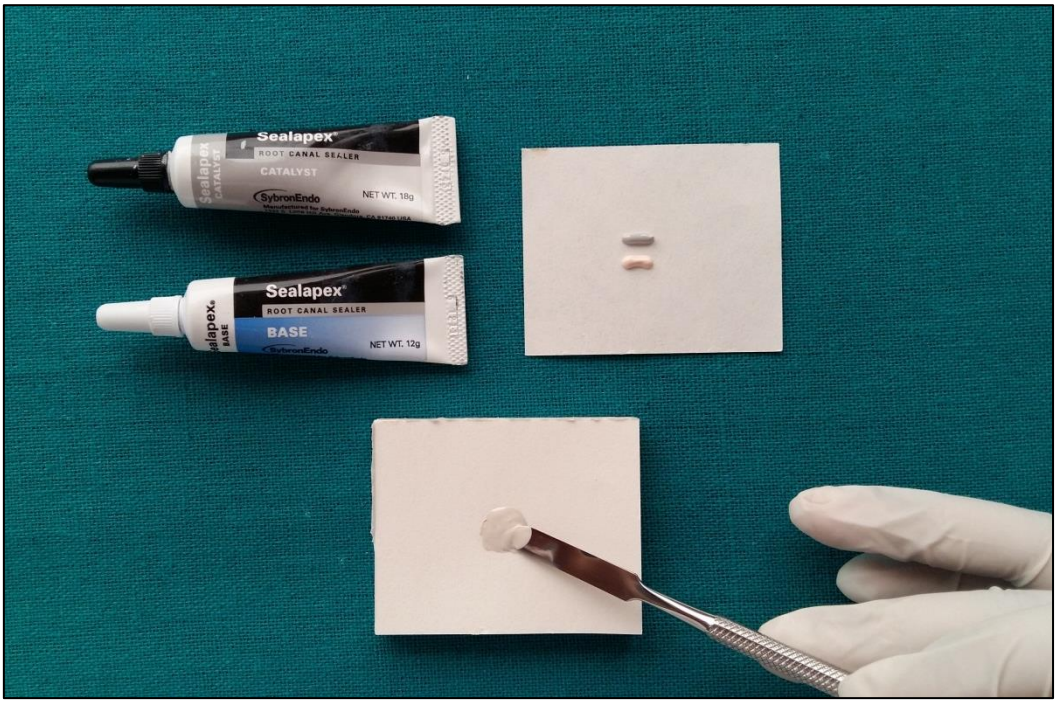


PHOTOGRAPH 7

MANIPULATION OF ZINC OXIDE EUGENOL BASED SEALER (TUBLI-SEAL EWT)

PHOTOGRAPH 8

MANIPULATION OF RESIN BASED SEALER (AH PLUS)

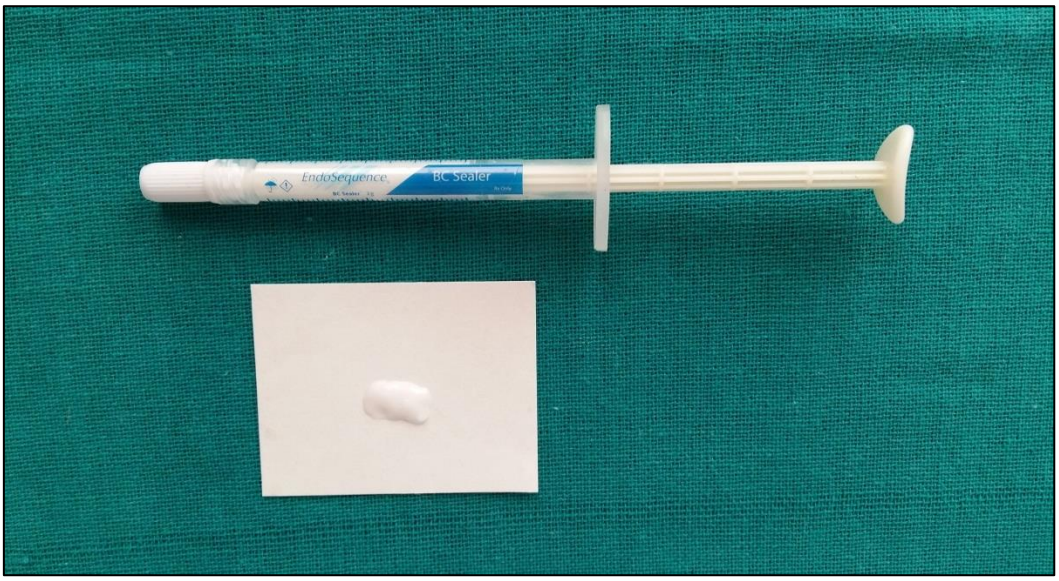


PHOTOGRAPH 9

MANIPULATION OF CALCIUM HYDROXIDE BASED SEALER (SEALAPEX)

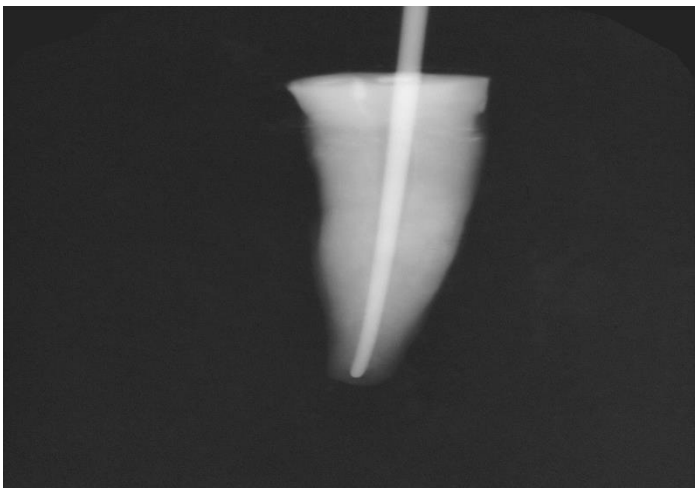
PHOTOGRAPH 10

DISPENSED MTA BASED SEALER (MTA FILLAPEX)



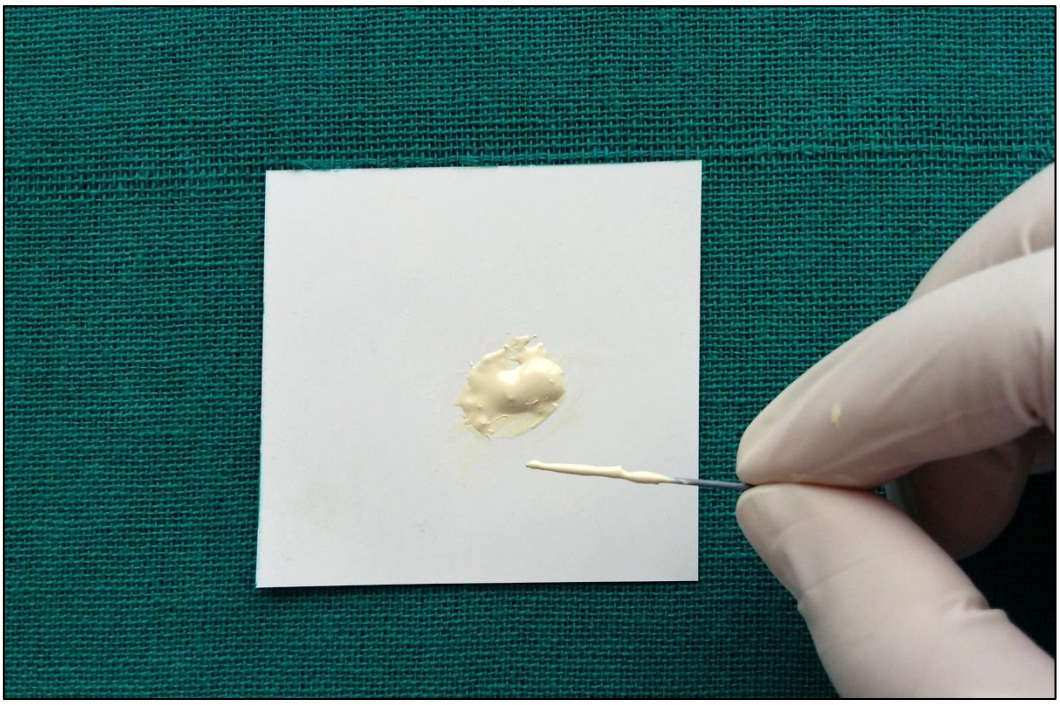
PHOTOGRAPH 11

DISPENSED BIOCERAMIC BASED SEALER (ENDOSEQUENCE BC)



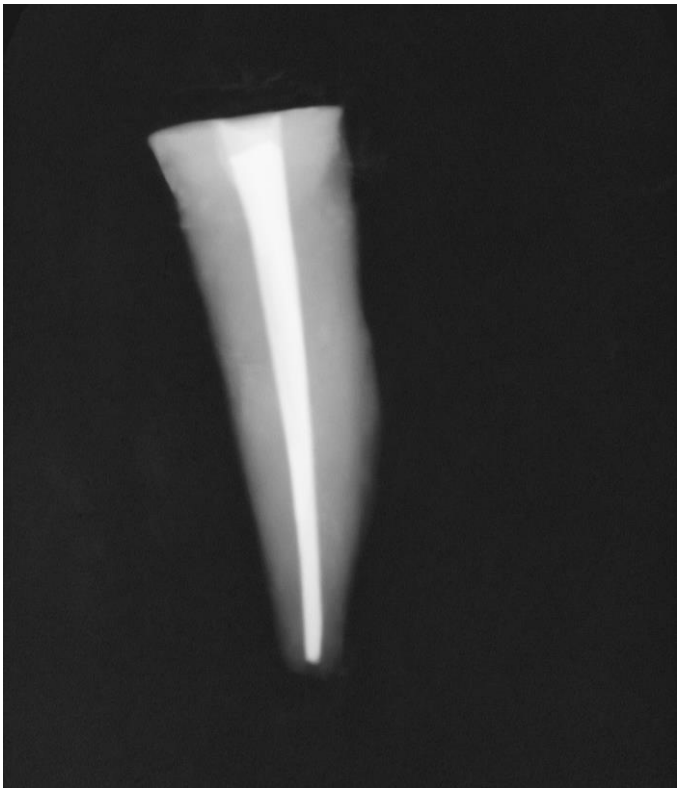
PHOTOGRAPH 12

MASTER CONE RADIOGRAPH



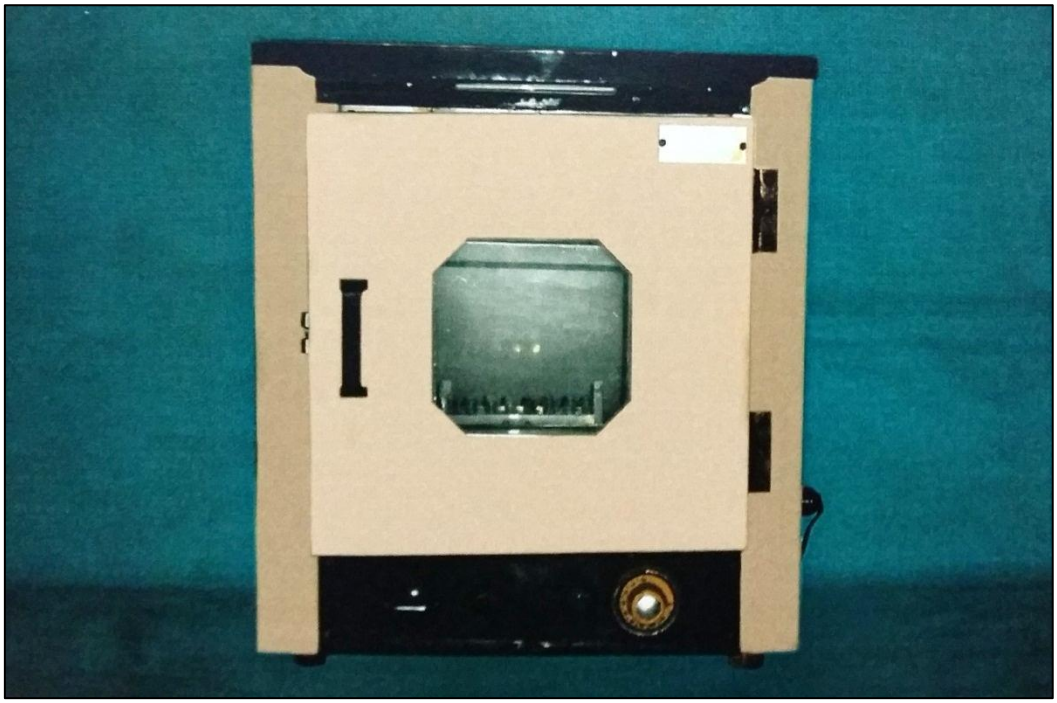
PHOTOGRAPH 13

COATING OF MASTER CONE WITH SEALER



PHOTOGRAPH 14

POST OBTURATION RADIOGRAPH



PHOTOGRAPH 15

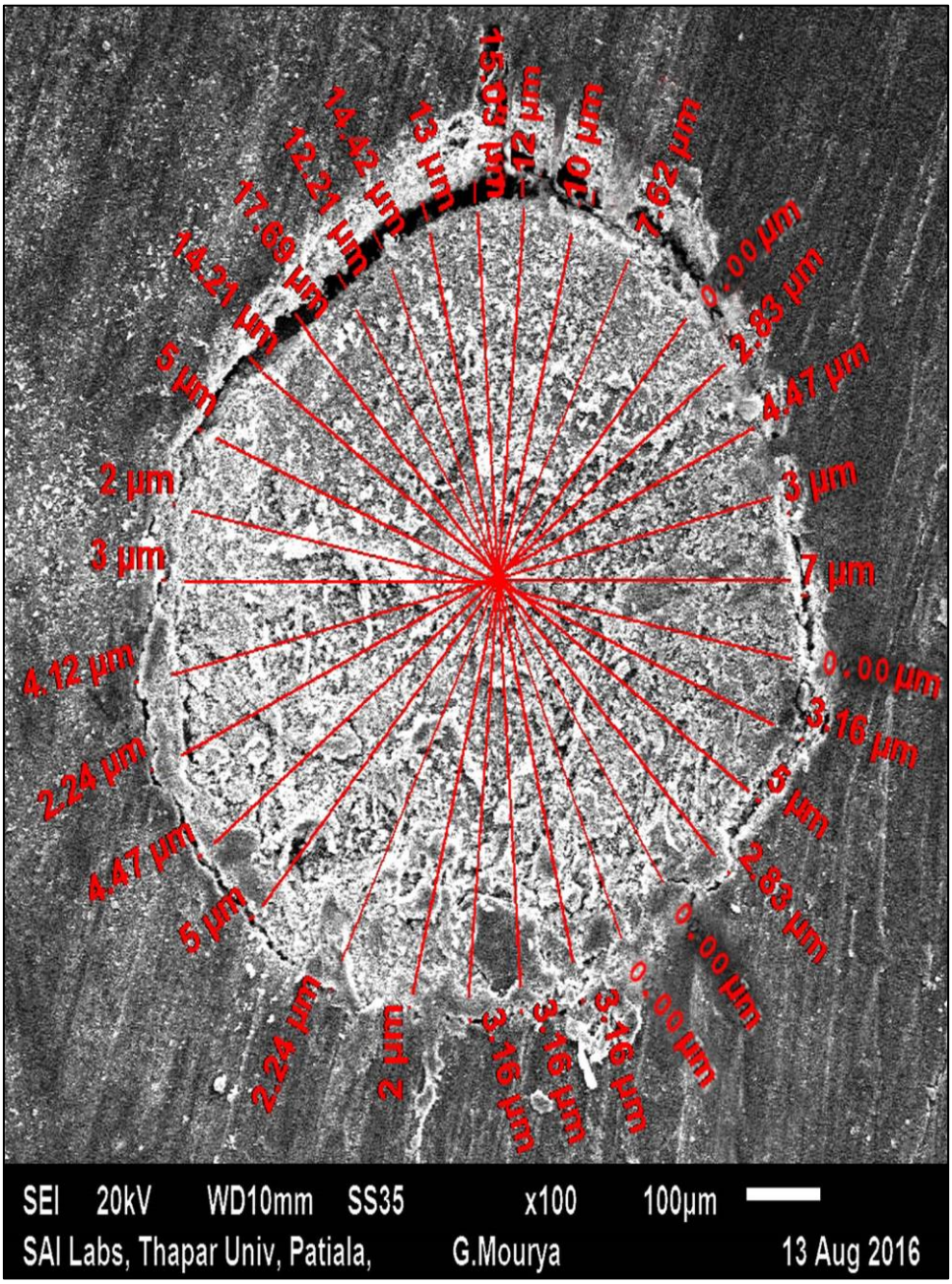
INCUBATOR

PHOTOGRAPH 16

SECTIONING OF SAMPLES

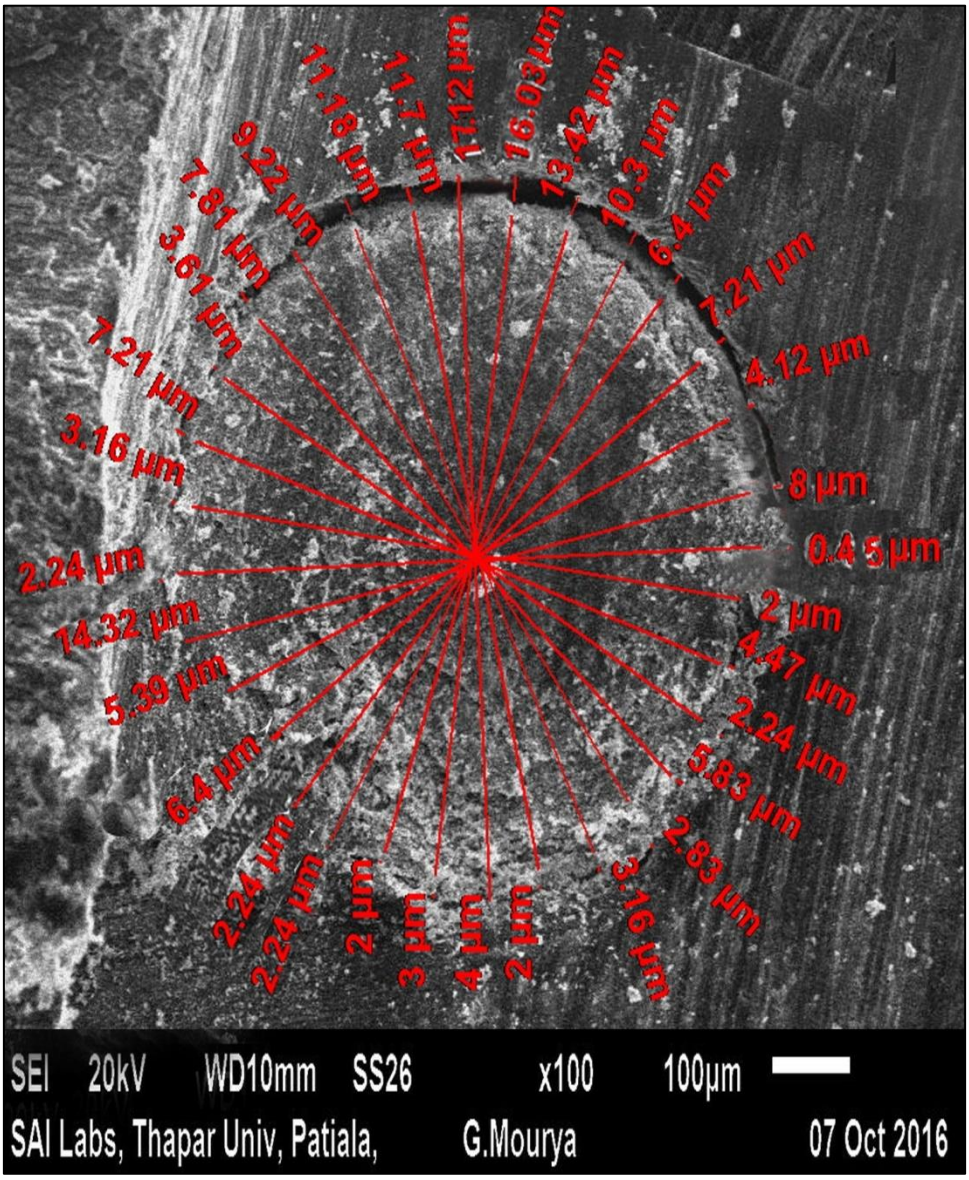
PHOTOGRAPH 17

SCANNING ELECTRON MICROSCOPE



PHOTOGRAPH 18

PHOTOGRAPH SHOWING GAP BETWEEN DENTIN AND SEALER IN MICROMETERS (µm)
SCANNING ELECTRON MICRSCOPIC VIEW (100 X)



PHOTOGRAPH 19

PHOTOGRAPH SHOWING GAP BETWEEN DENTIN AND SEALER IN MICROMETERS (µm)
SCANNING ELECTRON MICRSCOPIC VIEW (100 X)

METHOD

SAMPLE COLLECTION:

Freshly extracted human maxillary anterior teeth were collected from the Department of Oral and Maxillofacial Surgery, Guru Nanak Dev Dental College and Research Institute, Sunam.

SAMPLE SELECTION:

From the collected teeth, fifty teeth with closed apices without any visible evidence of root fracture, cracks and external resorption were selected for the study. Pre-operative radiographs of all the teeth were taken to rule out any variation in canal anatomy.

CLEANING OF THE SAMPLES:

All the surfaces of the selected teeth were debrided of adhering tissues with No. 15 scalpel blade and then disinfected by overnight immersion in 5% sodium hypochlorite solution.

DECORONATION (PHOTOGRAPH 4)

The anatomical crowns of all the selected teeth were removed by using diamond disc to obtain a uniform root length of 16mm from the apex.

WORKING LENGTH DETERMINATION (PHOTOGRAPH 5)

The root canal length of all the teeth was determined by placing a no. 10 stainless steel K-file (Mani Inc., Japan) into the canal until the tip was seen flushing with apical foramen. From this canal length, 0.5 mm was subtracted and the length thus obtained was recorded as working length.

INSTRUMENTATION:

Cleaning and shaping of root canals of all teeth were performed by step back technique using K-files with an apical enlargement upto size 40. During cleaning and shaping, the canals were irrigated with alternate use of 5% sodium hypochorite (NaOCl) and 17% Ethylene diamine-tetraacetic acid (EDTA). A final irrigation with normal saline was done in order to eliminate/neutralize the effects of NaOCl.

PLACEMENT OF INTRACANAL MEDICAMENT (PHOTOGRAPH 6)

After cleaning, the canals were dried with No. 40 absorbent paper points (EndoFirst) and then calcium hydroxide paste (Avuecal, Dental Avenue) was placed as an intracanal medicament using disposable plastic tips. Cotton pellet was placed above intracanal medicament to prevent temporary filling material to enter the canal. Then the access cavities were sealed with temporary filling material (Coltosol F, Coltene Whaledent). The teeth were incubated for seven days at 37°C and 100% humidity.

REMOVAL OF INTRACANAL MEDICAMENT:

After seven days, the calcium hydroxide was removed from the root canals using a small file and irrigation with alternate use of 5% sodium hypochlorite and 17% EDTA solution. This procedure of irrigation was continued till whole paste was removed from the root canal.

Teeth were then divided into five groups of ten samples each based on the sealer used for root canal obturation:

GROUP I - Zinc Oxide Eugenol based sealer (Tubli-Seal EWT, SybronEndo)

GROUP II - Resin based sealer (AH Plus Sealer, Dentsply Maillefer)

GROUP III - Calcium Hydroxide based sealer (Sealapex, SybronEndo)

GROUP IV - MTA Based sealer (MTA- Fillapex Sealer, Angelus)

GROUP V - Bioceramic based sealer (EndoSequence BC Sealer, Brasseler, USA)

GROUP-I (PHOTOGRAPH 7)

In each sample of this group, Zinc Oxide Eugenol based sealer (Tubli-Seal EWT, SybronEndo) was used during obturation which is available as a two paste system i.e. a base and a catalyst.

Base contains – zinc oxide, oleo resin, bismuth trioxide, thymol iodide, oils and waxes.

Catalyst contains- eugenol, polymerised resins and annidalin.

Both base and catalyst pastes were mixed in equal amount (1:1) for 20 to 30 seconds on a paper pad using a stainless steel spatula in a small area of about 1-2 cm diameter. The mixing was done in a circular motion while pressing the spatula hard to obtain a uniform consistency with no off-colour blotches or streaks. After taking master cone radiograph, the master cone was coated with mixed sealer and placed upto working length. **(Photograph 12, 13)**. The obturation was completed using lateral compaction technique.

GROUP-II (PHOTOGRAPH 8)

In each sample of this group, Resin based sealer (AH Plus Sealer, Dentsply Maillefer) was used for obturation which is available as two paste system:

Paste A containing epoxy resins

Paste B containing amines

Both Paste A and Paste B was mixed in equal lengths (1:1) on a mixing pad using a metal spatula to attain homogeneous consistency. The master cone was then coated with mixed sealer and the canal was obturated using lateral compaction technique.

GROUP-III (PHOTOGRAPH 9)

In each sample of this group, Calcium hydroxide based sealer (Sealapex, SybronEndo) was used which is available as two paste system i.e. a base and a catalyst.

Base contains- Calcium hydroxide, Zinc oxide, Calcium oxide, Butyl benzene, Fumed silica

Catalyst contains- Barium sulfate, Titanium dioxide, Zinc stearate, Disalicylate, Trisalicylate, Bismuth trioxide

Both base and catalyst pastes were mixed in equal lengths (1:1) on a mixing pad using a metal spatula for 15 to 20 seconds or until thoroughly blended. The mixing was done in a circular motion while pressing the spatula hard to obtain a uniform consistency. Samples were then obturated by lateral compaction technique as done in in Group I and Group II.

GROUP-IV (PHOTOGRAPH 10)

In each sample of this group, MTA based sealer (MTA- Fillapex Sealer, Angelus) was which is available as an automix dual syringe.

Paste A contains- Salicylate resin, Bismuth trioxide, Fumed silica

Paste B contains- Fumed silica, Titanium dioxide, MTA (40%), Base resin

The automixed sealer was dispensed on a paper pad and master cone was coated with it and obturation was completed using lateral compaction technique.

GROUP-V (PHOTOGRAPH 11)

In each sample of this group, Bioceramic based sealer (EndoSequence BC Sealer, Brasseler, USA) was used as a sealer for obturation which is available as a single paste system which was dispensed on a paper pad.

Sealer contains- Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents.

After coating mastercone with sealer, samples were obturated by lateral compaction technique as performed in in Group I and Group II.

CORONAL SEALING

After obturation of all the teeth, coronal access cavities were sealed with temporary filling material (Coltosol F, Coltene Whaledent). Radiographs were taken to confirm the quality of obturation. **(Photograph 14)**

SECTIONING OF THE SAMPLES:

All the prepared samples were then incubated at 37°C and 100% humidity for 72 hours to allow root canal sealers to set **(Photograph 15)**. The apical 3mm of each root was sectioned at 90 degree angle to the long axis of the tooth using diamond disc in micromotor contrangle handpiece (NSK). **(Photograph 16)**

EVALUATION AND COMPARISON:

The gap at interface of dentin and sealer was measured in micrometers using scanning electron microscope in all the five groups **(Photograph 18, 19)**. Each sample was divided into four quadrants and eight readings were recorded in each quadrant making it to 32 readings. The average of these 32 readings was taken as a mean gap of that particular sample. The data thus obtained was compiled and put under statistical analysis.

Review of Literature

Abramovich A et al (1976)[1] studied the relationship of different root canal sealers i.e. AH26, Diaket A, Tubli Seal and Grossman's cement and paste like Biocalex and Calcium Hydroxide to the dentin wall. He concluded that none of the materials used for obturation showed total obliteration of the dentinal tubules of the root canal wall. The difficulty of obliterating all the dentinal tubules in the root canal indicates that the sealers do not adhere but merely compressed against the canal wall.

Barnett F et al (1989)[11] compared the sealing ability of two different calcium hydroxide containing root canal sealers i.e. Calciobiotic root canal sealer and Sealapex. They concluded that Calciobiotic root canal sealer was better than Sealapex. They also concluded that calcium hydroxide containing sealers leaked significantly less than zinc oxide eugenol sealer.

Canalda- Sahli C et al (1992)[19] evaluated the apical seal of various root canal sealing cements using a radionuctide detection technique. 150 maxillary incisors and canines were prepared using step back technique. Teeth were then divided into various groups based on the sealer used for root canal obturation: two groups were obturated with zinc oxide eugenol based cements i.e. Endomethasone Tubliseal, two groups with cements based on plastic resins i.e. AH 26 and Diaket and two more groups with cements containing calcium hydroxide i.e. Sealapex and Calciobiotic Root Canal Sealer (CRCS). All the teeth were obturated using lateral condensation technique and the apical leakage was detected with the help of radionuctide detection technique. They observed that the best seal was achieved with Sealapex cement, which was significantly better than AH26, Tubtiseal, Diaket. The maximum leakage was obtained with Endomethasone and CRCS cement.

Nerwich A et al (1993)[64] evaluated pH Changes in root dentin over a 4-week period following root canal dressing with Calcium Hydroxide. Root canals of twelve teeth were cleaned and shaped using step back technique and subsequently dressed with calcium hydroxide. The pH Changes in the root dentin were measured over a 4-wk period with microelectrodes in small cavities at apical and cervical levels in inner and outer dentin. They observed that the pH increased within hours in the inner dentin, peaking at pH 10.8 cervically and 9.7 apically. However, the pH began to rise in the outer root dentin, reaching peak levels of pH 9.3 cervically and 9.0 apically after 2 to 3 wk. They concluded that hydroxyl ions derived from a calcium hydroxide dressing do diffuse through root dentin. They diffuse faster and reach higher levels cervically than apically.

Holland R et al (1995)[41] observed the quality of seal of the glass ionomer cement, Ketac-Endo, after treatment of the root canal wall. The root canals of 140 extracted human teeth were prepared using step back technique. Teeth were divided into four groups. In Group-1: root canals did not receive any treatment, in Group-2: root canals were treated with 20% EDTA for 5 min, in Group-3: root canals received a dressing of calcium hydroxide in glycol propylene as a creamy consistency for 24 hours and in Group-4: received a dressing of camphorated paramonochlorphenol on a paper point was given for 24 hours. After the removal of intra canal dressing all the groups were subdivided into 3 groups based on sealer used for root canal obturation i.e. Ketac-Endo, Zinc oxide-eugenol cement and Sealapex. All the teeth were obturated using lateral compaction technique. After 24 hours, the teeth were placed in a 2% methylene blue dye and the leakage was measured by linear dye penetration method with the help of stereomicroscope. They observed that Sealapex exhibited significantly less leakage than Ketac-Endo or zinc oxide-eugenol cement. They also observed that use of EDTA and intermediary dressings significantly reduced the leakage observed with the zinc oxide-eugenol and Ketac-Endo sealers.

Siqueira Jr JF (1995)[85] evaluated sealing ability, pH and flow rate of calcium hydroxide based sealer with zinc oxide eugenol based sealer. They found that calcium hydroxide based sealer had less microleakage, more flow and pH than zinc oxide eugenol based sealer.

Margelos J et al (1997)[57] studied the interaction of calcium hydroxide with zinc oxide eugenol sealer. Twenty single rooted teeth were prepared by step back technique and calcium hydroxide medicament was placed. Teeth were divided into four groups depending upon the irrigating solution used. Removal of calcium hydroxide was evaluated using 15% EDTA.2NaOH. They concluded that 15% EDTA.2NaOH improved the removal efficiency of calcium hydroxide except in apical area. They also concluded that when a ZnOE sealer was used for obturation in root canals treated previously with calcium hydroxide dressing, setting time of sealer was decreased.

Calt S et al (1999)[18] evaluated the dentinal tubule penetration of root canal sealers after root canal dressing with calcium hydroxide. They concluded that when only NaOCL was used as irrigant $Ca(OH)_2$ was not completely removed from the root canal surfaces and root canal sealers did not penetrate into the dentinal tubules. EDTA followed by NaOCI irrigation resulted in complete removal of $Ca(OH)_2$ and helped root canal sealers to penetrate into the dentinal tubules.

Lambrianidis T et al (1999)[53] studied the removal efficiency of different calcium hydroxide dressings i.e. Calxyl, Pulpdent paste, and chemically pure $Ca(OH)_2$ mixed with distilled water from the root canals with different irrigating solutions used i.e. saline, NaOCL and NaOCL and EDTA. They concluded that no statistically significant difference was found in the calcium hydroxide removal efficiency between Calxyl and

pure calcium hydroxide among the irrigating agents used. Pulpdent demonstrated significantly higher retention capacity than pure calcium hydroxide, regardless of the irrigation agent used. Probably methylcellulose, contained in Pulpdent to increase its handling properties, resists dissolution and removal of calcium hydroxide by the irrigation solutions.

Miletic I et al (1999)[59] evaluated the apical sealing ability of five different root canal sealers. Teeth were prepared using step back technique and were divided into five groups based on the use of root canal sealer i.e. AH26, AH Plus, Diaket, Apexit, and Ketac-Endo. All the teeth were obturated using lateral condensation technique and the sealing ability was measured with the help of a fluid transport model. They observed that there was no significant difference in the sealing ability of the five root canal sealers.

Almeida WAD et al (2000)[5] evaluated the apical sealing ability of three endodontic sealers i.e. zinc oxide eugenol sealer, glass ionomer sealer and epoxy resin sealer. They concluded that epoxy resin sealer had better sealing ability than zinc oxide eugenol and glass ionomer based sealer.

Barthel CR et al (2000)[12] compared the Bacterial leakage in obturated root canals following the use of different intracanal medicaments. After preparation with step back technique teeth were divided into four groups based on different intracanal medicaments. In first group 5% chlorhexidine gel in the second group Ledermix paste and in the third group fresh mix of calcium hydroxide and water was placed as intracanal medicament. In the fourth group no medicament was used. Teeth were then obturated with lateral condensation technique using AH26 root canal sealer and bacterial leakage was checked. They observed that none of the test samples leaked for three months. After one year, the calcium hydroxide group showed minimum leakage. They concluded that calcium hydroxide should be the medicament of choice to avoid bacterial penetration of the root canal.

Gaikwad B et al (2000)[32] evaluated the sealing ability of different sealers i.e. calcium hydroxide and zinc oxide eugenol when calcium hydroxide is used as an intracanal medicament. They recommened that when calcium hydroxide is used as medicament, calcium hydroxide based sealer should be used to obtain a better apical seal.

Cobankara FK et al (2002)[23] evaluated the microleakage of four different root canal sealers. After biomechanical preparation using step-back technique, teeth were divided into four groups based on the root canal sealer used i.e. Zinc oxide eugenol based sealer (Sultan), Epoxy resin based sealer (AH Plus), Glass inomer based sealer (Ketac-Endo) and Polydimethylsiloxane based sealer (RoekoSeal). All the teeth were obturated using lateral condensation technique and apical leakage was measured using fluid filtration method. They observed that RoekoSeal showed least microleakage followed by AH Plus and Ketac-Endo. Zinc oxide eugenol based sealer (sultan) showed maximum microleakage among the sealers tested.

Kim SK and Kim YO (2002)[49] compared the effect of calcium hydroxide on the sealing ability of gutta-percha root filling with a zinc oxide eugenol sealer. They concluded that calcium hydroxide intracanal medication may increase apical leakage when zinc oxide eugenol sealer is used**.**

Miletic I et al (2002)[60] evaluated the bacterial and fungal microleakage of AH26 and AH Plus root canal sealers. Teeth were prepared using step back technique and were divided into two groups based on the use of root canal sealer i.e. AH26 and AH Plus root canal sealer. All the teeth were obturated using lateral condensation technique. Bacteria used in the study were *Streptococcus mutans*, *Streptococcus mitis*, *Prevotella melaninogenica* and *Lactobacillus acidophilus*. *Candida albicans* was the fungi used for the study. After every 72 h bacterial and fungal growth was tested up to a period of 90 days. They observed that leakage was present in

almost half of all the samples. They concluded that gutta percha and the sealers AH 26 and AH Plus donot prevent bacterial and fungal leakage.

Sevimay S et al (2003)[81] evaluated dentinal penetration and adaptation of three endodontic sealers using scanning electron microscope. Biomechanical preparation using step-back technique was performed in decoronated maxillary anterior teeth. Samples were then divided into three groups based on the root canal sealer used i.e. AH 26 (epoxy resin-based sealer), Calcibiotic Root Canal Sealer (calcium hydroxide based sealer), Roeko Seal Automix (silicon based sealer). All the teeth were obturated using lateral condensation technique. The samples were stored in 100% humidity at 37ºC for one week and thereafter sectioned longitudinally in labio-lingual direction. The samples were prepared for examination under scanning electron microscope. They observed that AH 26 showed the best sealer penetration into the dentinal tubules followed by Roeko Seal Automix and Calcibiotic Root Canal Sealer.

Cobankara FK et al (2004)[24] evaluated the effect of the smear layer on apical and coronal leakage in root canals obturated with AH26 or RoekoSeal root canal sealer. 160 extracted maxillary anterior teeth were prepared upto size-7 with ProFile.06 taper Series 29 rotary instruments. Teeth were randomly divided into two groups of sample size of 80 each according to the presence or absence of the smear layer. In the smear positive group, the root canals were irrigated with 10 ml of 5.25% NaOCl only. To remove the smear layer in the smear negative group, teeth were irrigated with 10 ml 17% EDTA followed by 10 ml of 5.25% NaOCl. Both the groups were further divided into 4 sub-groups of 20 teeth each with all possible combinations of three factors: smear layer (present/absent), leakage assessment (apical/coronal), and sealer used (AH26/Roeko- Seal). All the teeth were obturated using lateral condensation technique and were stored in an incubator at 37°C and 100% humidity for 1 week. Apical and coronal leakage was measured using fluid filtration method. They observed that removal of the smear layer from the root canal walls before obturation significantly reduced the leakage of root canal sealers. They also observed that there was no statistically significant difference in either apical or coronal leakage between RoekoSeal and AH26, regardless of the presence or absence of the smear layer, however, the apical leakage was significantly higher than coronal leakage for both root canal sealers.

Sevimay S et al (2005)[82] evaluated the apical sealing ability and adaptation to dentin of two resin-based root canal sealers. Fifty five extracted maxillary anterior teeth were prepared using step back technique and were divided into two groups based on the root canal sealer used i.e. AH Plus and EndoRez. All the teeth were obturated using lateral condensation technique. Twenty teeth from each group were used for the apical leakage test using dye penetration method and the remaining five teeth from each group were used for examination under the scanning electron microscope (SEM) to measure adaptation and penetration of root canal sealers. They observed that AH Plus sealer had better apical sealing ability and adaptation to dentin than EndoRez sealer.

Cobankara FK et al (2006)[25] evaluated the apical sealing ability of four endodontic sealers i.e. Rocanal 2 (Zinc Oxide Eugenol based sealer), Sealapex (Calcium Hydroxide based sealer), AH Plus (Epoxy Resin based sealer), RC Sealer (Polymeric Resin based sealer). Forty extracted human maxillary anterior teeth were prepared using step back technique till apical size 55 and were divided into four groups of 10 teeth each based on the root canal sealer used. All the teeth were obturated using lateral condensation technique and were stored in 100% humidity at 37°C for 7 days. The apical sealing ability was measured after 7, 14, and 21 days using computerized fluid filtration method. They observed that Sealapex showed better apical sealing than the other sealers at 7, 14, and

21 days. RC Sealer, AH Plus and Rocanal 2 showed similar apical leakage values at every period. They also observed that the apical leakage of all sealers decreased gradually from 7 days to 21 days.

Dultra F et al (2006)[26] compared the apical sealing ability of four different root canal sealers. After biomechanical preparation of root canals teeth were divided into four groups based on the use of different root canal sealers i.e. Endofill, AH Plus, EndoREZ and Epiphany. All the teeth were obturated using lateral condensation technique and the apical leakage was measured with the help of microscope. They observed that EndoFill showed the highest dye penetration and dye penetration of Epiphany, EndoREZ and AH Plus was close to each other. They concluded that the resin based root canal sealers presented lesser apical microleakage than the zinc oxide-eugenol-based sealer.

Almeida JFA et al (2007)[4] evaluated the flow characteristics of AH Plus, Epiphany Root Canal Sealant, Endomethasone, Pulp Canal Sealer (EWT) and Sealapex and their ability to fill artificial lateral canals and prevent microleakage using the American Dental Association (ADA) 57 and the International Standards Organization (ISO) 6876 specifications. They concluded that all the sealers flowed into the 0.1 mm artificial lateral canals. AH Plus, Epiphany and Sealapex allowed less linear leakage than Pulp Canal Sealer (EWT).

Paque F et al (2007)[69] compared the long-term apical sealing ability of gutta-percha/AH Plus and Resilon/Epiphany. One hundred single-rooted mandibular premolars were prepared with ProFile 0.4 taper instruments to apical size 40 and were randomly divided into four groups of 20 samples each. In Group 1- Teeth were obturated with lateral compaction technique using gutta-percha and AH Plus sealer, Group 2- Teeth were obturated with vertical compaction technique using System B and Obtura II devices and AH Plus sealer, Group 3- Teeth were obturated with lateral compaction technique using Resilon cone and Epiphany sealer, Group 4- teeth were obturated with vertical compaction technique using System B and Obtura II devices and Resilon cone and Epiphany sealer. All the samples were allowed to set for 7 days at 37°C and 100% humidity. Subsequently, the root fillings were removed down to the apical 4 mm. Fluid movement was then assessed using a fluid transportation model and re-evaluated after 16 months of water storage. They observed that initially, Resilon/Epiphany root fillings prevented fluid movement to the same degree as guttapercha/ AH Plus sealer, but showed more fluid movement when tested at 16 months.

Asgary S et al (2008)[8] evaluated the antibacterial effects of five different root canal sealing materials i.e. Gray and White Mineral Trioxide Aggregate (GMTA and WMTA), Calcium Hydroxide (CH), Portland cement (PC) and a new endodontic cement (NEC). 45 base layers of Petri plates was made using Muller-Hinton agar and were divided randomly into five test groups based on different root canal sealing materials with eight plates each. Five cavities were made in agar and filled with fresh mixed materials after 24 h. *Pseudomonas aeruginosa*, *Enterococcus faecalis*, *Staphylococcus aureus*, *Escherichia coli* and a mixture of these bacteria were seeded by pour plate. The plates were preincubated for 2 h at room temperature followed by incubation at 37°C. The inhibition zone diameters were measured at 24, 48 and 72 h. They observed that Calcium Hydroxide and new endodontic cement consisting of different calcium compounds (i.e. Calcium Oxide, Calcium Phosphate, Calcium Carbonate, Calcium Silicate, Calcium Sulfate, and Calcium Chloride) showed significantly better antibacterial effect than Gray and White Mineral Trioxide Aggregate and Portland cement.

Saleh IM et al (2008)[78] evaluated bacterial penetration along different root canal filling materials in the presence or absence of smear layer. 110 single rooted human extracted teeth were prepared using Stainless steel K-files till final apical size 80 under irrigation with 1% NaOCl. Half of the roots were irrigated with a 5-mL

rinse of 17% EDTA. Roots with or without smear layer were then divided into 6 groups of 15 teeth each and were obturated with gutta-percha (GP) and AH Plus sealer (AH), GP and Apexit sealer (AP) and RealSeal cones and sealer (RS) and were stored in humid conditions 37°C for 7 days. Samples were then mounted into a bacterial leakage test model for 135 days and the day of leakage was recorded for each leaking sample and number of leaking samples per group. 3 samples from each group were then sectioned longitudinally and were observed under scanning electron microscope for the presence of bacteria at interfaces. They observed that removal of the smear layer did not impair the bacterial penetration along root canal fillings. They also observed that in the absence of smear layer RealSeal sealer leaked more than AH Plus sealer.

Zhang H et al (2009)[97] compared the antibacterial effectiveness of seven different endodontic sealers i.e. AH Plus, Apexit Plus, iRoot SP, Tubli Seal, Sealapex, Epiphany SE and EndoRez against *Enterococcus faecalis* using a modified direct contact test. They concluded that Fresh iRoot SP killed all bacteria in 2 minutes, AH Plus in 5 minutes, EndoRez in 20 minutes and Sealapex and Epiphany in 60 minutes. Freshly mixed Apexit Plus and Tubli Seal failed to kill all bacteria at 60 minutes. Tubli Seal and AH Plus did not show any significant antibacterial activity. Sealapex and EndoRez showed antimicrobial activity even at 7 days after mixing.

Agrawal N et al (2010)[2] studied the effect of zinc oxide eugenol based, silicone based and calcium hydroxide based sealer on apical seal when calcium hydroxide is used as an intracanal medicament. They concluded that when calcium hydroxide is used as medicament, calcium hydroxide based sealer should be preferred.

Bodrumlu E et al (2010)[17] evaluated the effect of three root canal irrigating solutions i.e. sodium hypochlorite, chlorhexidine and MTAD on the apical sealing ability of three different root canal obturating materials i.e. gutta-percha/AH plus, MM-seal and Resilon/ Epiphany SE. Teeth were obturated using lateral condensation method. They concluded that as compared to CHX group, the NaOCl and MTAD solution seem to create a more favourable surface for the root canal filling materials to achieve a better apical seal. The apical sealing ability of AH plus, Epiphany SE and MM-seal root canal sealers decreased when the chlorhexidine was used as an irrigation solution.

Poggio C et al (2010)[72] evaluated the solubility of six different root canal sealers including two ZnOE based sealers (Endomethasone C and Argoseal), two Calcium Hydroxide based sealers (Bioseal Normal and Acroseal), and two Resin based sealers (AH Plus and MM Seal). Ten samples of each material were prepared using stainless steel ring molds with an internal diameter of 20 ± 0.1 mm and a height of 1.5 ± 0.1 mm and immersed in water. All samples were left to set for 24 hours on a grating in a cabinet at 37˚C and 100% relative humidity. Solubility was determined by using sample weight loss (%) after 24 hours and after 2 months. They observed that Resin-based root canal sealers showed least solubility percentage followed by ZnOE based sealers and Calcium Hydroxide based sealers.

Vasconcelos BCD et al (2010)[91] evaluated the sealing ability of five different root canal sealer i.e. AH Plus, Acroseal, Sealapex, MTA-Obtura and MBP (experimental cement). They observed that AH Plus and MBP have lowest leakage values over 60 days. Acroseal, Sealapex, and MTA-Obtura have progressively increased leakage over extended periods that are from 15 to 60 days.

Balguerie E et al (2011)[10] evaluated the tubular adaptation and penetration of different root canal sealers. Fifty-two freshly extracted single-rooted permanent human teeth were prepared with nickel-titanium rotary files (HeroShaper; Micro-Mega) until apical file size 30. Samples were divided into five groups with sample size of 10 each based on the different root canal sealers used i.e. Calcium hydroxide epoxy resin based sealer

(Acroseal), Zinc oxide eugenol based sealer (Endobtur), Glass ionomer based sealer (Ketac-Endo), Epoxy resin based sealer (AH Plus), Silicon based sealer (RSA). All the teeth were obturated using hot gutta-percha carrier HeroFill size 30 (Micro-Mega) and were then stored at 37°C and 100% humidity for 2 weeks. Samples were then transversely sectioned at 2, 5, and 8 mm from the working length with a diamond wire saw and were evaluated under scanning electron microscope to measure the depth of sealer penetration in dentinal tubules. They observed that AH Plus showed the maximum tubular penetration and adaptation to the root canal wall of all the sealers tested.

Metkari SS et al (2011)[58] evaluated the apical sealing ability of Resilon and Epiphany SE root canal sealer when compared with gutta-percha and AH Plus sealer gutta-percha and Tubli-seal EWT using dye leakage approach. Sixty four human maxillary permanent central incisors were prepared using 0.04% taper NiTi rotary instrument system (K-3; SybronEndo) till apical size 40 and were divided into 3 groups with sample size of 20 each based on the use of different root canal sealers. All the teeth were obturated using lateral condensation technique and were kept in 100% humidity at 37°C for 7 days. Teeth were then immersed in 1% aqueous solution of methylene blue for 7 days at 37°C and were sectioned longitudinally. Apical leakage was measured using linear dye penetration method with the help of stereomicroscope. They observed that resilon and epiphany SE root canal sealer showed least apical leakage followed by AH Plus root canal sealer and Tubli-seal EWT root canal sealer respectively.

Oliveira MAVCD et al (2011)[67] evaluated the Influence of calcium hydroxide on marginal leakage of endodontically treated teeth. After biomechanical preparation of root canals half of the teeth were filled with a paste of pure CH powder mixed with normal saline solution as intracanal medicament. After seven days intracanal medicament was removed and all the teeth were obturated using the lateral condensation technique with zinc oxide-eugenol sealer and marginal leakage was evaluated at apical foramen and at middle third of the root canal. They concluded that remnants of CH intracanal medication led to lower dye penetration in length and depth at apical foramen and at middle third of the root canal.

Punitha PG et al (2011)[73] evaluated and compared the adaptation of resin based sealers Epiphany, AH Plus and AH 26 to root canal dentin using Scanning Electron Microscope (SEM). Sixty extracted single rooted maxillary central incisors were prepared using crown down technique, teeth were divided into three groups with twenty samples each based on the use of root canal sealer and were obturated using lateral compaction technique. The teeth were placed in 100% humidity at 37ºC for 72 hours. Each sample was sectioned longitudinally and adaptation of sealer was examined under Scanning Electron Microscope. Ten samples of each group were examined in middle third and ten samples in apical third. They observed that Epiphany showed best adaptation to root canal dentin followed by AH Plus and AH 26 respectively.

Yahya MM (2011)[95] evaluated the sealing ability of mineral trioxide aggregate (MTA) as a root canal sealing material via comparing its apical sealing ability with zinc oxide based sealer. Twenty eight single rooted teeth were cleaned and shaped and divided into two groups based on the type of sealer used i.e. MTA (mineral trioxide aggregate) and zinc oxide based sealer. All the teeth were obturated using lateral condensation technique. Apical leakage was checked using dye penetration method with the help of stereomicroscope. They concluded that mineral trioxide aggregate (MTA) provide better apical seal than zinc oxide based root canal sealer.

Amin SAW et al (2012)[7] evaluated the effect of calcium hydroxide intracanal placement on the bond strength of two calcium silicate–based and an epoxy resin–based endodontic sealer. The root canals of ninety maxillary central incisors were prepared with protaper size F5, teeth were then divided into three groups based on the canal conditions i.e. Group 1: no prior intracanal $Ca(OH)_2$ placement before root canal filling, Group 2: calcium hydroxide paste was injected into the canal using a special tip introduced at least 2 mm short of the apex and then slowly withdrawn and after one week $Ca(OH)_2$ was removed by irrigation using 5 mL distilled water and the manual use of ProTaper followed by a final flush of 5mL distilled water. Group 3: $Ca(OH)_2$ was placed as in group 2 and then removed by irrigation using 5 mL 2.5% NaOCl and the manual use of ProTaper followed by passive ultrasonic irrigation (PUI) of 5 mL 2.5% NaOCl then final flush using 17% EDTA for 1 minute followed by 5mL distilled water. Each group was subdivided into 3 subgroups according to the sealer used as follows: AH Plus, iRoot SP and MTA Fillapex and the push-out bond strength was measured with the help of universal testing machine. They observed that regardless of intracanal medication used, AH Plus showed highest bond strength followed by iRoot SP and MTA Fillapex. It was also observed that iRoot SP showed increased bond strength in calcium hydroxide treated groups.

Assmann E et al (2012)[9] evaluated the bond strength to root dentin of two mineral trioxide aggregate (MTA) based sealers (Endo-CPM sealer and MTA fillapex) and one epoxy resin-based sealer (AH Plus sealer). Forty-five human extracted teeth were prepared using step back technique and were divided into three groups based on the root canal sealer. All the teeth were obturated using lateral condensation technique and the push out test was performed using universal testing machine. They observed that Endo-CPM sealer showed the highest bond strength to root dentin followed by AH Plus sealer and MTA fillapex. They also observed that inspite of having maximum bond strength Endo-CPM showed more bacterial leakage than resin based sealer.

Bier CAS et al (2012)[16] evaluated the push-out bond strength of Calcium hydroxide and Mineral Trioxide Aggregate based sealers to root canal dentin. The adhesiveness of six root canal sealers i.e. Acroseal, Endo CPM, Epiphany, White MTA, Sealapex and Sealer 26 to dentin was tested with push-out technique in a mechanical testing machine. They observed that Acroseal, Sealer 26, and Epiphany presented the highest shear bond strengths followed by white MTA, Endo CPM Sealer and Sealapex respectively.

Gomes-filho JE et al (2012)[34] evaluated the apical sealing ability of two MTA containing sealers i.e. Fillapex and Endo-CPM Sealer and calcium hydroxide containing Sealer i.e. Sealapex. They concluded that Sealapex and Fillapex leaked singnificantly less than Endo-CPM Sealer and the results obtained for sealapex and fillapex were similar.

Hamidi MR et al (2012)[40] evaluated the effect of Calcium Hydroxide and Chlorhexidine medicaments on the Apical Seal. After preparation with step back technique teeth were divided in three groups, Group 1 had root canal dressing with calcium hydroxide; group 2 had root canal dressing with 1% chlorhexidine gel and group 3, did not receive a dressing. After removing the dressings after seven days, all teeth were obturated by a cold lateral condensation technique using AH26 root canal sealer and apical leakage was checked using dye penetration method. They concluded that Calcium hydroxide group had the least apical leakage at 2 mm level whilst chlorhexidine group showed the maximam apical leakage.

Joseph R et al (2012)[47] compared the sealing ability of four different sealers using centrifuging dye penetration method. Teeth were obturated with lateral condensation technique using AH26, Sealapex, Endoflas FS and AH Plus sealers. They observed lowest dye penetration in AH Plus group followed by Endoflas FS, Sealapex, AH

26.They concluded that AH Plus showed the best sealing ability among the four different sealers used for root canal obturation.

Kumar RV and Shruthi CS (2012)[52] compared the sealing ability of zinc oxide eugenol based, resin based and glass ionomer based sealer when used with lateral compaction technique. They concluded that resin cement sealed the root canals significantly better than zinc oxide eugenol and glass ionomer sealers.

Mallya L et al (2012)[56] compared the contact angle of calcium hydroxide to the radicular dentin using different aqueous vehicles i.e. distilled water, chlorhexidine and anesthetic solution and non-aqueous vehicles i.e. glycerin, propylene glycol and iodoform. They concluded that aqueous vehicles such as distilled water, Chlorhexidine and anesthetic solution are better than nonaqueous vehicles to carry calcium hydroxide into the root canals and to achieve the best contact of calcium hydroxide with the radicular dentin. The results showed that among the aqueous vehicles used, distilled water showed better result than the other aqueous vehicles having the least contact angle, thus better wettability.

Nagas et al (2012)[62] evaluated the effect of intraradicular moisture conditions on the push-out bond strength of different root canal sealers. Eighty extracted human teeth were prepared with rotary files and were divided into four groups according to moisture conditions tested i.e. Group 1: Dry- excess distilled water was removed with paper points followed by dehydration with 95% ethanol, Group 2: Normal moisture-the canals were blot dried with paper points with the last one appearing dry, Group 3: Moist- the canals were dried with low vacuum by using a Luer adapter for 5 seconds followed by 1 paper point for 1 second and Group 4: Wet-the canals remained totally flooded with water. The roots were then obturated using different root canal sealers i.e. AH Plus, iRootSP, MTA Fillapex and Epiphany. The bond strength was evaluated using universal testing machine and failure was analysed with the help of stereomicroscope. They observed that irrespective of the moisture conditions, iRoot SP showed the highest bond strength to root dentin followed by AH Plus, Epiphany and MTA Fillapex. Moist group showed the highest bond strength than all the groups tested irrespective of the sealer.

Singh CV et al (2012)[84] compared the penetration depth of two resin-based sealers (AH plus and Resino Seal) and Zinc Oxide Eugenol sealer into the dentinal tubules after removing smear layer. Thirty maxillary central incisors were prepared using step back technique. Teeth were divided into three groups based on the use of different sealers i.e. AH Plus sealer, Resino Seal sealer and Zinc Oxide Eugenol sealer. All the teeth were obturated using lateral condensation technique and the sealer penetration depth was examined under scanning electron microscope. They observed that AH Plus showed maximum penetration depth into dentinal tubules followed by Resino Seal sealer and Zinc Oxide Eugenol sealer.

Sonmez IS et al (2012)[86] evaluated the apical microleakage of a new MTA based sealer i.e. MTA Fillapex. After biomechanical preparation teeth were divided into three groups i.e. group1: obturation was done with gutta-percha and AH Plus sealer using lateral condensation technique, group 2: obturation was done with gutta-percha and MTA Fillapex using lateral condensation technique, group 3: obturation was done using Pro Root MTA, group 4: obturation was done with gutta-percha without a sealer using lateral condensation technique. All the teeth were immersed in methylene dye and the apical microleakage was measured using linear dye penetration method with the help of a microscope. They observed that The MTA Fillapex group showed significantly higher microleakage than Pro Root MTA and AH Plus groups. They also observed that the sealing ability of Pro Root MTA was similar to AH Plus root canal sealer.

Tummala M et al (2012)[89] compared the wetting behavior of three different root canal sealers on the root canal dentin surface treated with different irrigants and their combination. Twenty seven single rooted teeth were divided into three groups based on different irrigants used i.e. Group 1 was treated with 17% ethylene diamine tetra acetic acid (EDTA), Group 2 was treated with 3% sodium hypochlorite (NaOCl) and Group 3 was treated with combination of 17% EDTA and 3% NaOCl. Each group was subdivided into three subgroups of 6 specimens each depending on the sealer used, i.e. sub group A: Zinc oxide eugenol based sealer; sub group B: AH plus sealer; and, subgroup C: Guttaflow and the contact angle was measured. They observed that within the ZnOE sealer group, there was no statistically significant difference seen in the contact angle values between any of the irrigants used. On the contrary, in the AH Plus group, NaOCl treated surface showed a significantly higher contact angle value, as compared to the other two groups whereas in Gutta-Flow, the root canal dentin surface treated with EDTA+NaOCl showed statistically significant lower contact angle value compared to the root canal dentin treated with EDTA alone. They also observed that the wettability of AH Plus sealer on the root surface dentin was found to be better than Gutta-Flow and ZnOE sealer.

Ali SA et al (2013)[3] compared the apical sealing ability of Resin based (AH26) and Calcium hydroxide based (Sealapex) sealers. After preparation with step back technique, teeth were obturated with cold lateral condensation technique and were suspended in 2% methylene blue dye. They concluded that resin based sealer (AH26) exhibited less leakage as compared to a Calcium hydroxide based sealer (Sealapex).

Bhardwaj V (2013)[14] evaluated the apical leakage of different root canal sealers. After biomechanical preparation using step-back technique, teeth were divided into three groups based on root canal sealer used i.e. AH-26 root canal sealer, AH-Plus root canal sealer, Resilon sealer. All the teeth were obturated using lateral condensation technique. The samples were stored in saline for 48 hours. The samples were then subjected to dye penetration test using 2% methylene blue. Apical leakage was measured with the help of stereomicroscope. They observed that Resilon sealer showed minimum apical leakage followed by AH Plus and AH-26 root canal sealer.

Ersahan S et al (2013)[29] evaluated solubility and apical sealing characteristics of a new calcium silicate-based root canal sealer in comparison to calcium hydroxide based, methacrylate resin based and epoxy resin-based sealers. Solubility was assessed by immersing standardized samples of iRoot SP (calcium silicate based sealer), Sealapex (calcium hydroxide based sealer), EndoREZ (methacrylate resin based sealer) and AH Plus (epoxy resin based sealer) in distilled water and measuring weight gain and weight loss at 6 h, 24 h and daily for 14 days. To measure apical sealing ability, 80 extracted mandibular premolars were prepared with 0.04-taper nickel-titanium rotary files (Revo-S) to a final apical size 40 and were divided into four groups with sample size of 18 each based on the use of different root canal sealers. All the teeth were obturated using lateral condensation technique and were stored at 37ºC and 100% humidity for 1 week. Apical microleakage was measured using fluid filtration method. They observed that 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. AH Plus exhibited significantly lower microleakage than Sealapex and EndoREZ, whereas no difference in microleakage was found between AH Plus and iRoot SP.

Malik G et al (2013)[55] studied comparative evaluation of intracanal sealing ability of mineral trioxide aggregate and glass ionomer cement. They concluded that MTA group leaked significantly less than glass ionomer group whereas Calcium hydroxide sealer exhibited better sealing ability than zinc oxide eugenol sealer.

Nainan MT et al (2013)[63] compared efficacy of 17% ethylene diamine tetra acetic acid and 7% maleic acid in the removal of 3 calcium hydroxide preparations i.e. pure calcium hydroxide mixture with distilled water, ApexCal and Metapex placed as intracanal medicaments. They concluded that 17% EDTA and 7% maleic acid were found to remove Pure calcium hydroxide mixture with distilled water and ApexCal efficiently, whereas 7% maleic acid was found to perform better than 17% EDTA in removing Metapex from the root canals.

Sadeghi S et al (2013)[76] compared the apical sealing ability of different root canal sealers. After preparation with step back technique teeth were obturated with different root canal sealers i.e. AH26, MTA Fillapex and white MTA alone. Lateral compaction method was used with AH26 and MTA Fillapex sealer and white MTA was filled with vertical compaction method into root canals and the sealing ability was observed using dye penetration method. They concluded thatAH26 sealer showed better apical sealing ability than MTA Fillapex sealer and MTA. There was no significant difference between apical sealing ability of MTA Fillapex and MTA.

Setia P et al (2013)[80] compared the apical sealing ability of two root canal sealers i.e. Hybrid Root SEAL (dual cure resin sealer) and iRoot SP (bioceramic sealer) when used along with conventional gutta-percha cones. 60 maxillary anterior teeth were prepared using step back technique. Teeth were divided into two groups depending on the sealer used and all the teeth were obturated using lateral compaction method. The apical leakage was checked using methylene blue dye penetration method with the help of spectrophotometer. They concluded that apical sealing ability of iRoot SP was better than Hybrid Root SEAL.

Wong JG et al (2013)[93] evaluated microleakage of adhesive resin materials in root canals. Root canals of straight single rooted bovine teeth were prepared with headstrom files and were divided into seven groups based on the sealer used for obturation i.e. adhesive resin materials: (Real Seal, Real Seal XT, Panavia F 2.0, Infinity Syringeable and GCEM), Zinc oxide-eugenol sealer (Tubli-seal) and Epoxy resin sealer (AH Plus). Samples were kept in water and were thermocycled before subjected to linear stain penetration method. Microleakage was measured with the help of monocular toolmakers microscope. They observed that least microleakage was shown by adhesive resin materials followed by Epoxy resin sealer (AH Plus) and Zinc oxide-eugenol sealer (Tubli-seal).

Bidar M et al (2014)[15] evaluated the effect of smear layer on apical seal produced by two calcium silicate-based endodontic sealers i.e. iRoot SP and MTA Fillapex. 82 single rooted teeth were prepared using step back technique and were divided into four groups. In Group 1: smear layer was retained and canals were obturated using gutta-percha and iRoot SP root canal sealer, in Group 2: the root canals were irrigated with 17% EDTA to remove the smear layer and canals were obturated using gutta-percha and iRoot SP root canal sealer, in Group 3: smear layer was retained and canals were obturated with gutta-percha and MTA Fillapex and in Group 4: the root canals were irrigated with 17% EDTA to remove the smear layer and canals were obturated with gutta-percha and MTA Fillapex. Leakage was evaluated with the help of fluid filtration technique after two weeks and three months. They observed that there was significantly less microleakage in root canals obturated with iRoot SP than with MTA Fillapex, regardless of the presence of the smear layer. They also observed that there was no significant difference between the smear-positive and smear-negative groups for root canals obturated with MTA Fillapex. For root canals filled with iRoot SP, leakage was greater in the smear-positive group than in the

smear-negative group after 2 weeks. However, after 3 months, microleakage did not significantly differ between groups.

Ehsani M et al (2014)[27] evaluated the apical micro-leakage of different endodontic sealers in the presence and absence of moisture. After biomechanical preparation teeth were obturated using different sealers i.e. AH26, Excite DSC, MTA Fillapex, and ZOE sealers under both dry and moist root canals conditions. All the teeth were then immersed in methylene blue dye and the dye penetration was measured with the help of stereomicroscope. They observed that the lowest apical micro-leakage was seen in AH26 sealer followed by Excite DSC, MTA Fillapex and the highest apical micro-leakage was related to ZOE sealer. They also observed that mean apical micro-leakage in all sealers was significantly lower on dry canal conditions compared with that in moist canal conditions, except for MTA Fillapex sealer which had no significant difference in micro-leakage rate between the two conditions.

Garg N et al (2014)[33] compared the apical sealing ability produced by zinc oxide eugenol sealer, calcium hydroxide based sealer, Glass ionomer root canal sealer and epoxy resin root canal sealer. After biomechanical preparation of one hundred and twenty extracted mandibular and maxillary human anterior teeth using step back technique, teeth were divided into four groups of thirty teeth each based on the use of root canal sealer i.e. zinc oxide eugenol sealer, calcium hydroxide based sealer (Metapex), Glass ionomer root canal sealer (Ketac Endo) and epoxy resin root canal sealer (AH Plus).All the teeth were obturated using lateral condensation technique and were immersed in 2% methylene blue dye for seven days. The apical leakage was measured using linear dye penetration method with the help of stereomicroscope. They observed that ketac endo showed the best sealing ability followed by AH Plus, Metapex and Zinc oxide eugenol sealer.

Jayasenthil A et al (2014)[46] compared the apical sealing ability of three root canal sealers. Thirty four extracted single rooted mandibular premolars were prepared using step back technique and samples were divided into three groups of ten teeth each based on the root canal sealer used i.e. Pulp canal sealer zinc (Zinc oxide eugenol based sealer), AH Plus (Epoxy resin based sealer), Roekoseal (Silicon based sealer). All the teeth were obturated using lateral compaction technique and were coated with nail varnish except for 1 mm surrounding the foramen area and the samples were stored in 100% humidity at 37°C for 7 days after which the microleakage was evaluated using fluid filtration method. They observed that AH Plus showed best apical sealing ability followed by Roekoseal and Pulp canal sealer.

Kuci A et al (2014)[50]evaluated sealer penetration into dentinal tubules in the presence or absence of smear layer. Forty five single rooted teeth were prepared with Self-Adjusting File with continuous sodium hypochlorite irrigation and then samples were divided into eight groups with sample size of five each i.e. Group A: canals were treated with EDTA/NaOCl and filled with AH26 root canal sealer using cold lateral compaction technique, Group B: canals were treated with EDTA/NaOCl and filled with MTA Fillapex using cold lateral compaction technique, Group C: canals were treated with EDTA/NaOCl and filled with AH26 using warm vertical compaction technique, Group D: canals were treated with EDTA/NaOCl and filled with MTA Fillapex using warm vertical compaction technique, Group E: canals were treated with NaOCl and filled with AH26 using cold lateral compaction technique, Group F: canals were treated with NaOCl and filled with MTA Fillapex using cold lateral compaction technique, Group G: canals were treated with NaOCl and filled with AH26 using warm vertical compaction technique, Group H: canals were treated with NaOCl and filled with MTA Fillapex using warm vertical compaction technique. Each sample was sectioned horizontally at 4 mm, 8

mm and 12 mm distance from apical tip and sealer penetration into dentinal tubules was examined under confocal laser scanning microscope. They observed that regardless of the usage of EDTA, MTA Fillapex was associated with greater sealer penetration when used with the cold lateral compaction technique as compared to AH26 and conversely AH26 was associated with greater sealer penetration when used with the warm vertical compaction technique as compared to MTA fillapex.

Masudi SM et al (2014)[57] compared the efficiency of 5.25% sodium hypochlorite (NaOCl) in conjunction with 17% ethylene diamine tetra acetic acid (EDTA) and EDTA with tension-active agent (SmearClear) for the removal of calcium hydroxide ($Ca(OH)_2$) from root canals and to determine the root canal wall cleanliness at the coronal, middle and apical third regions. He concluded that both EDTA irrigation solutions with or without tensioactive agent produced effective root canal cleanliness at the coronal and middle third regions. However, 17% EDTA was superior in removing the $Ca(OH)_2$ at the apical third region compared to SmearClear irrigation solution.

Pacios MG et al (2014)[68] evaluated the effect of calcium hydroxide pastes and vehicles i.e. Distilled water, chlorhexidine, carticaine in the anesthetic solution, propylene glycol, monochlorophenol and monochlorophenol propylene glycol on root canal dentin microhardness. They concluded that viscous and oily vehicles alone and associated to calcium hydroxide, reduced dentin microhardness more than aqueous vehicles i.e. all vehicles and pastes, except distilled water, significantly decreased the microhardness of the root dentin.

Pawar SS et al (2014)[70] evaluated the apical sealing ability of bioceramic sealer, AH plus and epiphany using dye penetration. They concluded that bioceramic sealer showed least dye penetration as compared to AH Plus sealer and epiphany in both horizontal and vertical directions.

Pupneja D (2014)[74] evaluated effect Of Moisture Level in root canal dentin on sealing ability of three different types of sealers. Thirty six freshly extracted premolars with single canal were instrumented by using hand files. The teeth were divided into 3 experimental groups of 12 teeth each according to sealer used: Group 1-ZOE based sealer, Group 2- Ca(OH)2 based sealer and Group 3- AH26 (resin based sealer). Groups were subdivided into 4 subgroups based on method used for moisture removal: a) paper points followed by 95% ethanol for 10 seconds. b) blot dried until the last paper point appeared dry. c) Vacuum adapter operating at low vacuum for 5 seconds followed by 1 paper point for 1 second. d) Canals remained totally wet. Teeth were then obturated using different sealers with lateral compaction technique. Apical leakage was checked using dye penetration method with the help of traveling microscope. They observed that Resin based sealers showed significantly less leakage than zinc oxide eugenol and calcium hydroxide based sealers. They also observed that Zinc oxide eugenol based sealers & calcium hydroxide based sealers showed least leakage when dried with paper points followed by 95% ethanol for 10 seconds. Moreover resin based sealers showed least leakage with vacuum adapter operating at low vacuum for 5 seconds followed by 1 paper point for 1 second. However when canals remained totally wet all groups showed maximum leakage.

Razavian H et al (2014)[75] evaluated bacterial leakage in root canals obturated with resin-based and mineral trioxide aggregate-based sealers. Teeth were prepared using step back technique and were divided into groups based on the use of root canal sealer i.e. AH26 root canal sealer and MTA fillapex. All the teeth were obturated using lateral condensation technique. Bacterial microleakage was evaluated using *Enterococcus faecalis* for 90 days and data was analysed by survival test. They observed that teeth obturated with AH26 root canal sealer showed less bacterial microleakage as compared to teeth obturated with MTA Fillapex.

Tandan M et al (2014)[88] evaluated the effect of four different intracanal medicaments i.e. Calcium hydroxide powder mixed with distilled water, Calcium hydroxide gutta percha points (calcium hydroxide points), 1% chlorhexidine gel (hexigel) and Chlorhexidine gutta percha points (Roeko Activ Points) on the apical seal of the root canal system. Fifty teeth were divided into five groups depending upon the medicament used. After 14 days the teeth were obturated using lateral compaction method. The apical leakage was evaluated using dye extraction method with the help of a spectrophotometer. They observed that 1% chlorhexidine gel had the maximum amount of leakage as compared to the calcium hydroxide powder mixed with distilled water.

Elbatouty KM et al (2015)[28] evaluated the push-out bond strength of bioceramic root canal sealer (EndoSequence BC) in comparison to a resin-based (AH Plus) sealer and a zinc oxide-eugenol-based (Kerr EWT) sealer. After biomechanical preparation of 63 human maxillary central incisors teeth were divided into three groups based on the sealer used for root canal obturation i.e. group 1-EndoSequence BC, group 2-AH Plus and group 3- Kerr EWT. All the teeth were obturated using lateral compaction technique. Each group was further subdivided into three subgroups according to the time interval until the push-out test: subgroup A- after 7 days; subgroup B- after 14 days; and subgroup C- after 30 days and push out bond strength was evaluated using universal testing machine. They observed that EndoSequence BC samples showed the highest mean push-out bond strength after 1 week and after 4 weeks followed by AH Plus. After 2 weeks, the AH Plus samples showed the highest mean push-out bond strength. Kerr EWT showed the lowest push-out bond strength mean values at all-time intervals. They concluded that after 4 weeks EndoSequence BC sealer provided superior bonding to root canal dentine than zinc oxide-eugenol and the AH Plus sealer.

Janavathi et al (2015)[45] compared the apical sealing ability for four different root canal sealers. Teeth were prepared using step back technique, canals were then obturated by lateral condensation method with different sealers like Tubliseal, Sealapex, AH plus and Endorez. Dye leakage method with methylene blue was used to evaluate sealing ability. They concluded that Endorez showed the least apical microleakage followed by AH Plus, Sealapex, and Tubliseal.

Mokhtari H et al (2015)[61] evaluated the apical leakage of teeth obturated with gutta-percha and three different sealers (resin- and zinc oxide eugenol-based) with/without smear layer.100 single rooted anterior teeth were prepared by step back technique. Teeth were divided in three groups based on the sealer used i.e. AH-26, Adseal and Endofil. Then each of the group was divided into two subgroups based on removal or maintaining of smear layer. All the teeth were obturated using lateral compaction method and apical leakage was checked using liner dye penetration method with the help of stereomicroscope. They observed that AH26 root canal sealer was superior to other sealers in preventing microleakage. They also observed that the presence of smear layer did not significantly affect the sealing ability of the sealers.

Seelan RG et al (2015)[79] compared the antimicrobial efficacy of different root canal sealers i.e. Tubli-Seal, Apexit Plus, Fillapex, AH Plus, RoekoSeal against Enterococcus faecalis using real-time polymerase chain reaction. They observed that the maximum antimicrobial activity was achieved with AH Plus followed Tubli-Seal, Fillapex, Apexit Plus and the least antimicrobial efficacy with RoekoSeal.

Khader MA et al (2016)[48] evaluated the dentinal tubule penetration depth of three root canal sealers using scanning electron microscope. Thirty extracted single rooted mandibular premolars were prepared using step back technique and samples were divided into three groups based on the root canal sealer used i.e. Zinc oxide eugenol-based sealer (Tubli-Seal), Calcium Hydroxide based sealer (Apexit Plus) and Resin-based sealer (AH

Plus). Teeth were obturated using lateral condensation technique and were stored in an incubator at 37°C and 100% humidity for 15 days. Samples were then sectioned longitudinally and depth of penetration of different sealers was observed using scanning electron microscope. They observed that AH Plus showed maximum dentinal tubular penetration followed by Apexit Plus and Tubli-Seal respectively.

Sonu KR et al (2016)[87] evaluated the dentinal penetration of three different endodontic sealers with and without smear layer removal. Sixty single rooted teeth after biomechanical preparation were divided into three groups based on the sealer used i.e. GuttaFlow 2, MTA Fillapex and AH Plus. Groups were further divided into two subgroups in which either the smear layer was removed or retained. All the teeth were obturated using lateral compaction technique and sealer penetration was examined under scanning electron microscope at cervical, middle and apical third of root. They concluded that depth of sealer penetration was more in subgroups where smear layer was removed compared with those without removal of the smear layer. They also concluded that GuttaFlow 2 showed the minimum penetration and AH Plus showed the maximum sealer penetration depth at cervical, middle and apical levels of the root canal.

DISCUSSION

Elimination of microbial contamination from the root canal system is a pre-requisite to the successful outcome of root canal treatment. Chemo mechanical cleaning and shaping of the root canals greatly reduce the number of bacteria, but it is impossible to obtain complete disinfection in all cases.[88]

Following instrumentation and irrigation, the use of inter-appointment medication has been widely advocated. The intracanal medicament will assist in the disinfection of the root canal system. Such medication should be effective throughout its period of application, and penetrate the dentinal tubules, eliminating bacteria that may be present, with little toxicity to the periradicular tissues. Various intracanal medicaments like calcium hydroxide, antibiotics, steroids etc. have been tried but calcium hydroxide based intracanal medicaments are considerd as gold standard.[94]

Since its introduction by Hermann in 1920, Calcium hydroxide has been used as an intracanal medicament based on its antibacterial, anti-resorptive and tissue dissolving properties.[94]

Various materials have been considered as vehicle for calcium hydroxide as intracanal medicament including distilled water, glycerine, normal saline solution, ringer's solution, dental anaesthetic solution, metacresyl acetate, camphorated monochlorophenol etc.[32]Calcium hydroxide should ideally be placed deep and densely in the canal space so that it biologic effects can be exerted in close proximity to the appropriate tissue. Placement of conventional or commercial paste is carried out with reamers, files, special syringes or lentulospirals.[2]

Calcium hydroxide should be completely removed from the root canal to obtain a fluid tight seal of the permanent root canal filling.[2] As its complete removal is problematic, some calcium hydroxide may be retained in the apical area **Lambrianidis et al. (1999).[49]** There is a concern that, at the time of root-canal filling, the retention of calcium hydroxide on the canal wall might affect the quality of the seal and influence the prognosis of the treatment. **Holland et al (1995)[41]** observed that when calcium hydroxide dressing was retained in the canal, apical leakage increased with time.

This present in vitro study was undertaken to compare the sealing ability of five different root canal sealers – Calcium hydroxide based sealer, Zinc oxide-eugenol based sealer, Silicon based sealer, MTA based root canal sealer and Bio-ceramic based root canal sealer when calcium hydroxide is used as an intracanal medicament under scanning electron microscope.

IN VITRO STUDY

A total fifty freshly extracted human maxillary anterior teeth with closed apices without any visible evidence of root fracture, cracks and external resorption were collected. Surfaces of all the selected teeth were debrided of adhering tissues by using No. 15 scalpel blade and then disinfected by overnight immersion in 5% sodium hypochlorite solution to remove any remaining adhering tissues.

The anatomical crowns of all the selected teeth were removed by using diamond disc to obtain a uniform root length of 16 mm from the apex. According to **Chandrasekhar P et al (2016)**[20] decoronation assures standardization of specimens. Then, root canal length of all the teeth was determined by placing a no. 10 stainless steel K-file into the canal until the tip was seen flushing with apical foramen. From this canal length, 0.5 mm was subtracted and the length thus obtained was recorded as working length. **Kuttler (1955)**[6] recommended that all root canal procedures should terminate 0.5 mm short of the apical foramen, as this point is considered to be the nearest to the apical constriction.

Root canals were then prepared by step back technique with K-files with an apical enlargement upto size 40. According to **Ciucchi B et al (1990)**[22] step-back technique produces a well tapered, smooth and centered preparation of root canal with a definite apical stop. **Chow TW (1983)**[21] stated that irrigants are unable to reach the apical portion of the root if the canal is not enlarged to size #40 file. During root canal preparation, 5% sodium hypochlorite and 17% EDTA were used as intracanal irrigants. **Saini D et al (2008)**[77] suggested that 5% sodium hypochlorite is very effective in removing organic debris and 17% EDTA removes smear layer. **White et al (1984)**[2] reported that the presence of the smear layer prevented the entry of filling materials into the dentinal tubules which decreased retention between material and the dentin wall and disrupt the apical seal.[2]

After cleaning, the canals were dried the canals with No. 40 absorbent paper points and calcium hydroxide paste (Avuecal, Dental Avenue) was placed as intracanal medicament using disposable plastic tips**. Sjogren et al (1997)**[54] showed a significant increase in prognosis of tooth when infected root canals were dressed with calcium hydroxide for one week before obturation. Cotton pellet was placed above intracanal medicament to prevent temporary filling material to enter the canal. Then the access cavities were sealed with temporary filling material (Coltosol F, Coltene Whaledent). Temporary filling materials provide an adequate seal against ingress of bacteria, fluids and organic materials from the oral cavity to the root-canal system, and at the same time prevent seepage of intracanal medicaments. The teeth were incubated for seven days at 37°C and 100% humidity in an incubator as recommended by **Agrawal N et al (2010)**[2]**.**

After seven days, the calcium hydroxide was removed from the root canals using a small file and irrigation with alternate use of 5% sodium hypochlorite and 17% EDTA solution. According to **Gulabivala K et al (2014)**[37]calcium hydroxide is easily removed by irrigating with sodium hypochlorite. However, weak acids such as EDTA enhance its removal leaving a cleaner canal wall as viewed by SEM.

Teeth were then divided into five groups of ten samples each based on the sealer used for root canal obturation.

GROUP-I

In each sample of this group, Zinc Oxide Eugenol based sealer (TubliSeal –EWT) was used as a sealer during obturation. They have been used as standard controls in several in vitro investigations for comparison to other endodontic sealers.[26] Tubli-Seal EWT is available as a two paste system i.e. a base and a catalyst. Both base and catalyst paste was mixed in equal amount (1:1) on a sterile glass slab using a stainless steel spatula to attain a creamy consistency. The master cone was then coated with sealer and placed upto working length. The obturation was completed using lateral compaction technique. Lateral compaction technique was preferred as it is the most frequently used technique, clinically effective and is the standard to which all other obturation techniques are compared **Inge JI et al (2008).**[44] Moreover, it is easy to perform and does not require any specialized equipment.

GROUP-II

In each sample of this group, Resin based sealer (AH Plus) was used as a sealer for obturation. AH plus has gained popularity due to its radiopacity, biocompatibility, ease to use and availability. AH Plus is an epoxy-bis-phenol resin based sealer that also contains adamantine and bonds to root canal[70]. AH Plus Sealer is available as two paste system. Both Paste A (epoxy resins) and Paste B (amines) was mixed in equal lengths (1:1) on a mixing pad using a metal spatula to attain homogeneous consistency. The master cone was then coated with sealer and the canal was obturated using lateral compaction technique.

GROUP-III

In each sample of this group, Calcium hydroxide based sealer (Sealapex) was used. Sealapex has antibacterial activity, good biological properties, high pH, calcium ion release, and good radiopacity.[30] Sealapex is available as two paste system i.e. a base and a catalyst. Both base and catalyst pastes were mixed in equal lengths (1:1) on a mixing pad using a metal spatula. Similarly as done in Group I and Group II the canal was obturated by lateral compaction technique.

GROUP-IV

In each sample of this group, MTA based sealer (MTA Fillapex) was used as a sealer. It is a calcium silicate based sealer which is known to possess favourable biocompatibility, antimicrobial activity and good sealing ability.[50] MTA- Fillapex Sealer is available as an automix dual syringe. The automix was dispensed on a paper pad and master cone was coated and obturation was completed using lateral compaction technique.

GROUP-V

In each sample of this group, Bioceramic based sealer (Endosequence BC) was used as a sealer for obturation. Endosequence BC sealer being biocompatible with low particle size, hydrophilicity and low contact angle, enable the cement to spread easily over the dentin walls of the root canal and get inside and fill the lateral microcanals. These features lead to the formation of a chemical bond between the sealer and the dentinal walls that make it an effective sealer.[80] EndoSequence BC Sealer is available as a single paste system which was dispensed on a paper pad. The master cone was then coated with sealer which was placed upto working length. The obturation was completed using lateral compaction technique. After obturation of all the teeth, coronal access was sealed with temporary filling material (Coltosol F, Coltene Whaledent). Radiograph was then taken to confirm the quality of obturation.

All the prepared samples were then incubated at 37°C and 100% humidity for 72 hours to allow root canal sealers to set as recommended by **Gusiyska A et al (2016).**[38] The apical 3mm of each root was sectioned at 90 degree angle to the long axis of the tooth. After sectioning the samples, the gap at interface of dentin and sealer was measured under scanning electron microscope and the readings were recorded in micrometers.

To evaluate the apical sealing ability of sealers, tracers like dyes, radioisotopes, bacteria and their products, such as endotoxins and other methodologies like fluid filtration and dye extraction method, scanning electron microscope etc. have been used. Scanning Electron Microscope was used in this study as it gives a three dimensional picture of a surface being scanned along with the added advantage of having a wide range of magnification and a greater depth of focus. **(Nigam V et al)**[65]

The results of the present study show that the least mean gap score i.e. 4.34µm (Table 4) was observed in Group IV in which teeth were obturated with MTA based sealer (MTA Fillapex) whereas the highest mean gap score i.e. 6.50µm (Table 1) was observed in Group I in which teeth were obturated with Zinc Oxide Eugenol based sealer (Tubli-Seal EWT).

The mean gap score observed in Group II was 4.96µm (Table 2) in which teeth were obturated with Resin based sealer (AH Plus).The mean gap score observed in Group III was 6.10µm (Table 3) in which teeth were obturated with Calcium Hydroxide based sealer (Sealapex). The mean gap score in Group V was 5.02µm (Table 5) in which teeth were obturated with Bioceramic based sealer (EndoSequence BC).

GROUP I in which the root canals were obturated with Zinc Oxide Eugenol based sealer (Tubli-Seal) has more gap at interface of dentin and sealer i.e. 6.50 µm than GROUP II in which root canals were obturated with Resin based sealer (AH Plus) i.e. 4.96 µm. When compared statistically, the difference in the mean gap between two groups was statistically highly significant (p<0.001).

Janavathi et al (2015)[45] compared the apical sealing ability of ***Tubliseal,*** Sealapex, ***AH plus***, and Endorez using dye leakage method. They observed that Tubli-Seal had more apical leakage than AH Plus sealer as they have poor adhesion and more permeability.

The results of our study are in congruence with the above study.

Khader MA et al (2016)[48] evaluated the dentinal tubular penetration depth of ***Tubli-Seal***, ***AH Plus*** and Apexit Plus sealer using Scanning Electron Microscope. They observed that Tubli-Seal showed less dentinal tubular penetration than AH Plus sealer which was due to fast setting reaction and less flow of Tubli-Seal.

Dultra F et al (2006)[26] compared the apical sealing ability of four different root canal sealers i.e. ***Zinc Oxide Eugenol based sealer*** (Endofill), ***AH Plus***, EndoREZ, Epiphany. They concluded that resin based root canal sealers show lesser apical microleakage than Zinc Oxide Eugenol based sealer. AH Plus has resin component in their formulations which improve their adherence to the intracanal dentin walls and is important factor for leakage prevention.

GROUP I in which the root canals were obturated with Zinc Oxide Eugenol based sealer (Tubli-Seal) has more gap at interface of dentin and sealer i.e. 6.50 µm than GROUP III in which root canals were obturated with Calcium Hydroxide based sealer (Sealapex) i.e. 6.10 µm. When compared statistically, the difference in the mean gap between two groups was statistically non-significant (p>0.05).

Gaikwad B et al (2000)[32] evaluated the sealing ability of ***Calcium Hydroxide and Zinc Oxide Eugenol based sealers***. They observed that in cases where calcium hydroxide is used as an intracanal medicament, Calcium Hydroxide based sealer showed better apical sealing ability than zinc oxide eugenol based sealer. The reason for

the difference was that Zinc Oxide Eugenol is water soluble and has the disadvantage of being decomposed by water through a continuous loss of eugenol. This makes it a weak unstable material. Whereas Calcium Hydroxide based sealers show very little water sorption which improves its sealing qualities.

The results of our study are in congruence with the above study.

Agrawal N et al (2010)[2] studied the effect of ***zinc oxide eugenol based sealer (Tubliseal)***, silicone based sealer (Roekoseal) and ***calcium hydroxide based sealer (Sealapex*** & Acroseal) on apical seal. They concluded that when calcium hydroxide is used as an intracanal medicament, it shows better apical sealing ability than Tubliseal. This is because an intra canal medicament, calcium hydroxide was difficult to remove completely from the canal. So, when Zinc Oxide Eugenol based sealer was used, this remaining medicament might interfere with its sealing ability and results in formation of new compound Calcium Hydroxide –Eugenol. This produced compound was more soluble, had less sealing ability, had a greater film thickness and higher water sorption value than the original sealer. However, when Calcium Hydroxide based sealer was used, residual calcium hydroxide of intra canal medicament gets incorporated into the sealer during obturation and decreases the permeability of the sealer.

GROUP I in which root canals were obturated with Zinc Oxide Eugenol based sealer (Tubli-Seal) has more gap at interface of dentin and sealer i.e. 6.50 µm than GROUP IV in which the root canals were obturated with MTA based root canal sealer (MTA Fillapex) i.e. 4.34 µm. When compared statistically, the difference in the mean gap between two groups was statistically highly significant (p<0.001).

Kumar A et al (2016)[51] compared the area of voids in ***MTA based sealer***, resin based sealer, and ***zinc oxide-eugenol-based sealer***. They concluded that ***MTA based sealer (MTA Fillapex)*** had no voids in the apical and middle third sections. According to them, MTA Fillapex sealer is said to exhibit a setting expansion due to the presence of MTA. However, its setting results in the hydration of anhydrous mineral oxide compounds to produce calcium silicate hydrate and calcium hydroxide phases which produce expansion. This expansion is thought to enhance the seal and minimize the leakage associated with the MTA Fillapex.

GROUP I in which the root canals were obturated with Zinc Oxide Eugenol based sealer (Tubli-Seal) has more gap at interface of dentin and sealer i.e. 6.50 µm than GROUP V in which root canals were obturated with Bioceramic based sealer (Endo Sequence BC) i.e. 5.02 µm. When compared statistically, the difference in the mean gap between two groups was statistically highly significant (p<0.001).

Yang SE et al (2007)[96] compared the sealing ability of ***Bioceramic based root canal sealers***, Resin based sealer, ***Zinc oxide Eugenol based sealer*** and Calcium Hydroxide based sealer. They observed that Bioceramic based root canal sealers show better sealing ability than Zinc Oxide Eugenol based sealer. According to them, the Bioceramic based sealers adhere to the dentinal surfaces of the canal wall and penetrate in open dentinal tubules to greater distances than Zinc Oxide Eugenol based sealers because particles of the set Calcium Phosphate based sealer were smaller than the open dentinal tubules along the canal wall.

GROUP II in which the root canals were obturated with Resin based root canal sealer (AH Plus) has less gap at interface of dentin and sealer i.e. 4.96 µm than GROUP III in which root canals were obturated with Calcium Hydroxide based root canal sealer (Sealapex) i.e. 6.10 µm. When compared statistically, the difference in the mean gap between two groups was statistically significant (p< 0.05).

Joseph R et al (2012)[47] compared the apical sealing ability of four different sealers AH 26, ***Sealapex***, Endoflas FS and ***AH Plus*** using centrifuging dye penetration method. They concluded that AH Plus showed significantly

less apical leakage than Sealapex. Sealapex showed a significant volumetric expansion during setting due to water absorption which increased the solubility of Sealapex and can affected the sealing property and the caused high leakage.

The results of our study are in congruence with the above study.

Gusiyska A et al (2016)[38] analysed the apical sealing ability ***Resin based sealer, Calcium Hydroxide based sealer***, Zinc Oxide Eugenol based sealer, MTA based sealer and Gutta Flow 2 using dye penetration method. They concluded that Resin based sealers show better apical sealing ability than Calcium Hydroxide based sealers. During setting, Calcium Hydroxide based sealers showed a significant volumetric expansion during setting due to water absorption which increases its solubility and affects its sealing property.

GROUP II in which the root canals were obturated with Resin based sealer (AH Plus) has more gap at interface of dentin and sealer i.e. 4.96 µm than GROUP-IV in which root canals were obturated with MTA based root canal sealer (MTA Fillapex) i.e. 4.34 µm. When compared statistically, the difference in the mean gap between two groups was statistically non-significant (p> 0.05).

Nikhil V et al (2015)[66] compared the effect of three root canal sealer activation techniques on percentage and depth of sealer penetration of ***MTA Fillapex*** and ***AH Plus sealers***. They concluded that MTA Fillapex sealer exhibited better depth of penetration in the radicular dentinal tubules than AH Plus.

GROUP II in which the root canals were obturated with Resin based root canal sealer (AH Plus) has less gap at interface of dentin and sealer i.e. 4.96 µm than GROUP V in which root canals were obturated with Bioceramic based root canal sealer (Endo Sequence BC) i.e. 5.02µm. When compared statistically, the difference in the mean gap between two groups was statistically non-significant (p>0.05).

Haddad AA et al (2015)[39] evaluated and compared the sealer thickness and interface adaptation of Sankin Apatite III, MTA Fillapex, ***EndoSequence BC*** to root dentin against ***AH plus***. They concluded that AH Plus sealer showed less gaps than Bioceramic sealer. The superior adaptation of AH Plus sealer could be due to its ability to bond to root dentin chemically by reacting with any exposed amino groups in collagen to form covalent bonds between the epoxy resin and collagen. Unlike alkaline Bioceramic based sealers, AH Plus is slightly acidic and might result in self etching when in contact with dentin, thereby enhancing interfacial bonding and adaptation.

The results of our study are in congruence with the above study.

Gade VJ et al (2015)[31] evaluated and compared the push-out bond strength of root filled with ***Endosequence BC, AH Plus*** and Endomethasone N sealers using lateral condensation and thermoplasticized technique. They concluded that AH Plus sealer showed high bond strength than EndoSequenc BC sealer used with lateral compaction technique. They observed that the higher bond strength obtained with AH Plus may be associated with its ability to react with any exposed amino groups in collagen to form covalent bonds between the resin and collagen upon opening of the epoxide ring. Resin based sealer penetrates deeper into the dentinal tubules due to its flowability and long-term polymerization time, which might contributen to enhancing the mechanical interlocking between the sealer and dentin. Thus, a very low shrinkage while setting and long-term dimensional stability shown by AH Plus might also contribute to its observed bond strength.

GROUP III in which the root canals were obturated with Calcium Hydroxide based root canal sealer (Sealapex) has more gap at interface of dentin and sealer i.e. 6.10 µm than GROUP IV in which root canals were obturated with MTA based root canal sealer (MTA Fillapex) i.e. 4.34 µm. When compared

statistically, the difference in the mean gap between two groups was statistically highly significant (p<0.001).

Gomes-Filho JE (2012)[34] evaluated the apical sealability of ***MTA Fillapex***, Endo-CPM-Sealer and ***Sealapex*** endodontic sealers. They observed that MTA Fillapex show better sealing ability than Sealapex. This is because, MTA setting results in the hydration of anhydrous mineral oxide compounds to produce calcium silicate hydrate and calcium hydroxide phases which produces expansion against its confining margins, enhancing the seal and minimizing leakage.

GROUP III in which the root canals were obturated with Calcium Hydroxide based root canal sealer (Sealapex) has more gap at interface of dentin and sealer i.e. 6.10 µm than GROUP IV in which root canals were obturated with Bioceramic based root canal sealer (Endo Sequence BC sealer) i.e. 5.02 µm. When compared statistically, the difference in the mean gap between two groups was statistically significant (p<0.05).

Yang SE et al (2007)[96] compared the sealing ability of ***Bioceramic based root canal sealers***, Resin based sealer, Zinc oxide Eugenol based sealer and ***Calcium Hydroxide based sealer***. They concluded that Bioceramic based root canal sealers show better sealing ability than Resin based sealer, Zinc oxide Eugenol based sealer and Calcium Hydroxide based sealer. They observed that Bioceramic Based root canal sealers adhere to the dentinal surfaces of the canal wall and penetrate open dentinal tubules to greater distances as compared to other sealers tested.

GROUP IV in which the root canals were obturated with MTA based root canal sealer (MTA Fillapex) has less gap at interface of dentin and sealer i.e. 4.34 µm than GROUP V in which root canals were obturated with Bioceramic based root canal sealer (Endo Sequence BC) i.e. 5.02 µm. When compared statistically, the difference in the mean gap between two groups was statistically non-significant (p>0.05).

Zhou HM et al (2013)[98] evaluated the physical properties of five root canal sealers i.e. ***MTA Fillapex***, ***Endosequence BC***, AH Plus, ThermaSeal, Gutta-Flow, Pulp Canal sealer. They observed that MTA Fillapex had higher flow and film thickness. It has shorter working time, setting time and solubility than EndoSequence BC sealer. An acceptable flow within the working time is important for any endodontic sealer to reach and seal the apical foramen and lateral dentinal wall irregularities.

However, few studies have results in contrary to the above studies.

Gusiyska A et al (2016)[38] evaluated the apical sealing ability of five different sealers i.e. AH Plus, Apexit Plus, Zinc Oxide Based Sealer, MTA fillapex, Gutta Flow 2 using Dye Penetration Method. They concluded that AH Plus and Zinc Oxide Eugenol based sealer show better apical sealing ability than MTA Fillapex.

Pinto NMF et al (2015)[71] compared the apical sealing ability of MTA Fillapex, Sealapex, Pulp Canal Sealer and AH 26.They concluded that Sealapex has better apical sealing ability than MTA Fillapex.

Cobankara FK et al (2006)[25] compared the apical sealing ability of four endodontic sealers i.e. Sealapex, RC Sealer, AH Plus, Rocanal 2. They concluded that Sealapex has better apical sealing ability than AH Plus. They observed that Sealapex showed significant volumetric expansion during setting which created a better apical seal.

Shetty V et al (2015)[83] compared the apical sealing ability of three different root-canal sealers; Zinc Oxide Eugenol based sealer, Calcium Hydroxide based sealer and Resin based sealer using a spectrophotometric

method. They concluded that Zinc Oxide Eugenol based sealer showed better apical sealing ability than Resin based sealer and Calcium Hydroxide based sealer.

As our study was performed in-vitro conditions. Results obtained in in-vitro apical sealing studies cannot be directly extrapolated clinically, but they do permit comparisons. Thus, more in-vivo studies should be performed to know the exact apical sealing ability of sealers.

SUMMARY AND CONCLUSIONS

SUMMARY

- This in-vitro study "**Comparison of sealing ability of five different root canal sealers when calcium hydroxide is used as an intracanal medicament: A SEM study" compared the sealing ability of Zinc oxide eugenol based sealer (Tubli-Seal EWT), Resin based sealer (AH Plus), Calcium hydroxide based sealer (Sealapex), MTA based sealer (MTA Fillapex), Bioceramic based sealer (Endosequence BC) when calcium hydroxide is used as an intracanal medicament.**
- 50 freshly extracted teeth with single root canal anatomy were selected and were decoronated using diamond to obtain a uniform root length of 16 mm from the apex
- Cleaning and shaping of root canal of each tooth was performed by step back technique using K files with an apical enlargement upto size 40.
- After preparation of root canal, calcium hydroxide (Avuecal^{+}, Dental Avenue) was placed as intracanal medicament using disposable plastic tips. After sealing the access cavities with temporary cement the teeth were incubated for 7 days at 37°C. Calcium hydroxide dressing was removed after 7 days. The prepared root canals will be thoroughly dried with absorbent points and the master gutta-percha cone (Dentsply Maillefer) for each tooth was selected.
- Teeth were then divided into five groups of ten samples each based on the sealer used for obturation: i.e. **Tubli-Seal EWT, AH Plus, Sealapex, MTA Fillapex, Endosequence BC.**
- After obturation with lateral compaction technique, the access cavities were sealed with temporary cement. The roots were stored for 72 hours at 37°C and 100% humidity to allow the sealers to set.
- After that the roots were sectioned and examined under scanning electron microscope to check the gap at interface of dentin and sealer. The data thus obtained was put under statistical analysis.
- Results showed that the maximum mean gap score i.e. 6.50µm was observed in Group I (Table1) in which teeth were obturated with Zinc Oxide Eugenol based sealer (Tubli-Seal EWT).
- The minimum mean gap score i.e. 4.34 µm was observed in Group IV (Table 4) in which teeth were obturated with MTA based sealer (MTA Fillapex).
- The mean gap score observed in Group II (Table 2) was 4.96µm in which teeth were obturated with Resin based sealer (AH Plus).
- The mean gap score observed in Group III (Table 3) was 6.10µm in which teeth were obturated with Calcium Hydroxide based sealer (Sealapex).
- The mean gap score in Group V (Table 5) was 5.02µm in which teeth were obturated with Bioceramic based sealer (EndoSequence BC).

CONCLUSIONS

From the results of the present in vitro study **"Comparison of Sealing Ability of Five Different Root Canal Sealers When Calcium Hydroxide is Used as An Intracanal Medicament: A SEM Study" following conclusions can be drawn:-**

1. All the sealers used in this study i.e. Tubliseal EWT, AH Plus, Sealapex, MTA Fillapex, Endosequence BC showed gap at interface of dentin and sealer when calcium hydroxide is used as an intracanal medicament.
2. MTA Fillapex (MTA based root canal sealer) showed minimum gap at interface of dentin and sealer and maximum gap was showed by Tubli-Seal EWT (Zinc Oxide Eugenol based sealer).
3. Thus, MTA Fillapex (MTA based root canal sealer) can be recommended as sealer for obturation when Calcium Hydroxide is used as an intra-canal medicament.

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