COMPARATIVE EVALUATION OF THE EFFECT OF VARIOUS INTRACANAL MEDICAMENTS ON THE PUSH-OUT BOND STRENGTH OF MTA AND ENDOCEM MTA - AN IN VITRO STUDY

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BRANCH - IV

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This is to certify that the dissertation titled "**COMPARATIVE EVALUATION OF THE EFFECT OF VARIOUS INTRACANAL MEDICAMENTS ON THE PUSH-OUT BOND STRENGTH OF MTA AND ENDOCEM MTA - AN IN VITRO STUDY"** is a bonafide work done by **Dr.L.BRINDHA,** Postgraduate student, during the course of the study for the degree of **MASTER OF DENTAL SURGERY** in the speciality of **BRANCH-IV DEPARTMENT OF CONSERVATIVE DENTISTRY AND ENDODONTICS,** Vivekanandha Dental College for Women, Tiruchengode, during the period of 2017-2020.

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DECLARATION

TITLE OF DISSERTATION	**COMPARATIVE EVALUATION OF THE EFFECT OF VARIOUS INTRACANAL MEDICAMENTS ON THE PUSH-OUT BOND STRENGTH OF MTA AND ENDOCEM MTA - AN IN VITRO STUDY**
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CERTIFICATE – II

This is to certify that this dissertation work titled **"COMPARATIVE EVALUATION OF THE EFFECT OF VARIOUS INTRACANAL MEDICAMENTS ON THE PUSH-OUT BOND STRENGTH OF MTA AND ENDOCEM MTA - AN IN VITRO STUDY"** of the candidate **Dr.L.BRINDHA,** with registration Number **241717552** for the award of **MASTER OF DENTAL SURGERY** in the branch of **CONSERVATIVE DENTISTRY AND ENDODONTICS**. I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows 2% of plagiarism in the dissertation.

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ACKNOWLEDGEMENT

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4a772eec-18ce-456f-901a-26009dc2813c
https://www.researchgate.net/publication/46304908_Medication_with_Calcium_Hydroxide_Improved_Marginal_Adaptation_of_Mineral_Trioxide_Aggregate_Apical_Barrier
https://www.researchgate.net/publication/296636147_Comparative_Analysis_of_Calcium_Silicate-based_Root_Filling_Materials_Using_an_Open_Apex_Model

Instances where selected sources appear:

8

CONTENTS

INTRODUCTION

Most endodontic failures occur as a result of leakage of irritants from bacteria and their by-products from pathologically involved root canals. [1] Microorganisms play an essential role in pulpal and periapical disease. [2] Therefore, the purpose of endodontic treatment is to eliminate microorganisms from the root canal system and to prevent recontamination by creating a barrier between the oral microflora and the root canal system and periapical tissue. In reality, creating a fluid-tight seal apically, laterally and coronally is necessary to prevent recontamination and long-term clinical success. [3]

Gartner and Dorn described an ideal material for sealing the root-end cavities should be hermetically sealing the apex and thus preventing leakage of microorganisms and their by-products into the periradicular tissues. Other properties of those materials are, they should be non-toxic, non-carcinogenic, be biocompatible with the tissue fluids, non-resorbable, impervious to dissolution by tissue fluids, closely adapt to the dentinal walls of root end preparation, be radio opaque and dimensionally stable. The presence of moisture should not affect the sealing ability of the material to the surface of the root dentin. [4]

Hench gave the concept of bioactivity as, "A bioactive material is one that elicits a specific biological response at the interface of the material which results in the formation of a bond between the tissues and the material".[5] One of the characteristics of a bioactive material is its ability to form an apatite-like layer on its surface when it comes in contact with physiologic fluids. Calcium silicate-containing biomaterials has a characteristic feature of apatite formation. [6]

One such new material is Mineral Trioxide Aggregate. The mineral trioxide aggregate (MTA) is a hydraulic cement which sets in the presence of water and established as a root-end filling material. [7] Studies have shown that MTA not only exhibits good sealing ability, excellent long term prognosis, relative ease of manipulation and good biocompatibility but also favours tissue regeneration. [8]

MTA has many desirable properties and continues to be the gold standard for root-end filling material. However, some shortcomings of MTA have also been reported, including its long setting time, difficult handling, tooth discolouration.[9] Newer hydraulic silicate cements have recently been introduced in market place to overcome the limitations of MTA such as the long setting time and difficult handling properties.

Recently, MTA-derived pozzolan cement Endocem MTA, (Maruchi, Wonju, Korea) was introduced in the endodontic market. Endocem could set quickly even without adding a chemical accelerator. Instead, it contains small particles of pozzolan cement that provides rapid setting of the mix by increasing the surface contact with the mixing liquid. [10]

The root apex is of particular interest to endodontics because the stages of root development and the type of tissue present within the roots of teeth are significant to the practice of endodontics. The root begins to develop after the formation enamel and the dentin. Root development is only 62-80% i.e., 2/3rd of the root at the time of tooth eruption. [11] If due to trauma or caries exposure, the pulp undergoes necrosis, dentin formation ceases and root growth is arrested. The resultant immature root with the canal wider towards the apex than the cervical area will have an open apex which is also called as Blunder Buss Canal. [12] There are several causes of the pulp necrosis of immature permanent teeth which include trauma, dental caries, and the dental anomalies: dens invaginatus and dens evaginatus. [13]

There is absence of natural apical constriction which creates an endodontic challenge for complete asepsis and three dimensional obturation of the root canal system. Therefore, one of the aims of endodontic treatment is to form an apical barrier or a stop against which one can place root canal filling material avoiding extrusion. This technique is termed as apexification. Apexification or root end closure, is the process whereby a non-vital, immature, permanent tooth is induced to form a calcified barrier at the root apex which has lost the capacity for further root development. This barrier forms a matrix against which root canal filling or restorative material can be compacted without the fear of over extrusion. [14]

The management of necrotic immature, permanent teeth presents a clinical challenge because of incomplete root development, unfavourable crown to root ratio and poor long-term prognosis [15]. The resultant thin, dentinal walls and open apex make root canal debridement difficult and a lack of apical closure complicates the root filling procedure and the attainment of an apical ‘seal’. The thin dentinal walls also increase the risk of future root fracture of these teeth under occlusal forces. [16]

Intracanal medicaments are commonly used between endodontic treatment visits. Temporary endodontic cements do not provide seals that are tight enough to prevent contamination of the root canal coronally before and after the placement of permanent fillings. [17] On the other hand, when teeth with necrotic pulps are being treated, mechanical preparation by means of files and ultrasound and disinfection by abundant irrigation with alternating sodium hypochlorite and ethylenediamine tetraacetic acid solutions should be followed by disinfection with a intracanal antibacterial dressing. [18] These intracanal antibacterial dressing are temporary medicaments that help to eliminate microorganisms that might otherwise prevent periapical healing. [19] They may also provide a physical barrier to prevent recontamination of the root canal by periapical bacteria during the interappointment visits.[20] Clinical follow-up evaluation have shown the results that temporary intracanal dressings help with the periapical healing process. [21]

The use of Calcium hydroxide, in dentistry is well established and widespread. It was introduced to endodontics by Hermann in 1920 and has been widely used in multiple endodontic applications. [22] Calcium hydroxide has also been used in various formulations, such as a liner beneath restorations and as a pulp-capping agent [23]. It is often applied within the root canal system for the control of inflammatory root resorption after luxation and avulsion injuries for their better prognosis. [24] Calcium hydroxide is widely used as an interappointment intracanal medicament during endodontic therapy and in apexification procedures. [25]

When placed within the root canal space and periapically, Calcium hydroxide disassociates into calcium and hydroxyl ions and the hydroxyl ions diffuse through the dentinal tubules.[26] The high alkaline pH and antimicrobial properties of Calcium hydroxide is known for its effectiveness as an intracanal inter-appointment medicament. It also inhibits inflammatory root resorption and can be used as a barrier in apical closure in nonvital immature teeth.[27] However, when Calcium hydroxide is used widely in these applications, treatment time may extend from months to years before the desired effects are achieved.[28] Furthermore, it has been observed that Calcium hydroxide treated immature teeth show a high failure rate because of an unusual preponderance of root fracture and it has been suggested that the resultant failure is due to the changes in the physical properties of dentin by the Calcium hydroxide medicament.[29]

Dentin in its composition composed of both organic and inorganic components. Calcium (Ca) and Phosphorus (P) are the major inorganic components of dental hard tissue that are present in hydroxyapatite crystals. [30] The flexural strength of dentin might, in part, depend on an intimate link between its two main components, the hydroxyapatite crystals and the collagenous network. Part of the organic matrix is composed of acid proteins and proteoglycans containing phosphate and carboxylate groups. These organic substances may act as a connecting link between the collagen network and the hydroxyapatite crystals. Calcium hydroxide due to its high alkalinity, they neutralize or denature some of the acidic components and thereby weakening the dentin. [31]

Several medicaments have been proposed or used as an alternative to Calcium hydroxide. Ledermix (Riemser, Greifswald, Germany), an antibiotic-corticoid, has also been recommended as a routine intracanal medicament to relieve postoperative pain associated with acute apical periodontitis or by preventing external inflammatory root resorption in traumatically injured teeth.[32] An antibiotic/corticosteroid combination, Ledermix has been extensively used in various parts of the world in paste and cement forms as both a vital pulp dressing and a root canal medicament. Composition of the medicament are Triamcinolone acetonide and Demeclocycline calcium. [33]

Pain before, during and after endodontic therapy is of serious concern both to the patient and to the endodontist. To deal with symptoms, anti inflammatory agents have to be incorporated with these intracanal medicaments. The primary interests in developing Ledermix paste is the use of corticosteroids that control pain and inflammation associated with pulp and periapical diseases. [34]

These Interim medicaments should be completely removed from the root canal in order to maintain the sealing and bonding efficacy of the permanent root canal filling or biomaterials. [35] With an increasing interest in regenerative endodontic procedures, complete removal of medicaments become even more challenging, since they do not employ debridement protocols in order to preserve thin dentinal walls. As such, little is known about their potential effects on the bonding effectiveness of calcium silicate-based cements used in regenerative procedures.

AIM AND OBJECTIVE

AIM

To evaluate the effect of various intracanal medicaments, namely Calcium hydroxide and Antibiotic combined Steroid paste on the push-out bond strength of MTA and Endocem MTA.

OBJECTIVE

1. To evaluate the push-out bond strength of MTA after the application and removal of Calcium hydroxide as an intracanal medicament using Instron.
2. To evaluate the push-out bond strength of MTA after the application and removal of Ledermix paste as an intracanal medicament using Instron.
3. To evaluate the push-out bond strength of Endocem MTA after the application and removal of Calcium hydroxide as an intracanal medicament using Instron.
4. To evaluate the push-out bond strength of Endocem MTA after the application and removal of Ledermix paste as an intracanal medicament using Instron.
5. To compare the push-out bond strength of MTA and Endocem MTA with prior application of two different intracanal medicaments

REVIEW OF LITERATURE

Glen. E.Doyon et al (2005) conducted a study to determine if exposure to intracanal calcium hydroxide $Ca(OH_2)$ alters the fracture resistance of human root dentin and found that there is a significant decrease in peak load at fracture when exposed to USP Calcium hydroxide compared to 180-day groups exposed to saline or Metapaste.[36]

Suresh Nandhini et al (2006) The vehicles used to carry calcium hydroxide intracanal medicament are many and may affect the retrieval. Access cavities prepared in 40 single rooted anterior teeth were filled with either Metapex or pure calcium hydroxide powder in distilled water. Calcium hydroxide was retrieved from the root canals after 1 week using either 17% EDTA or 10% citric acid in combination with ultrasonic agitation. Volume analysis was done using spiral computed tomography. 10% citric acid was better than 17% EDTA for Metapex. The 17% EDTA was better in efficiently removing calcium hydroxide powder in distilled water than Metapex. Ten percent citric acid removed powder form of calcium hydroxide in distilled water better than Metapex.[37]

Rosenberg B et al (2006) measured the effect of calcium hydroxide root filling on the micro tensile fracture strength (MTFS) of teeth. Forty extracted human permanent maxillary teeth were collected and instrumentation done with hand and rotary files. The root canals were compacted with United States Pharmacopeia (USP) calcium hydroxide. The storage period was about 7, 28, and 84 days in a moist environment. 10 teeth were vertically compacted with gutta percha and sealer and serves as a control group. The Microtensile fracture strength of the samples was measured (Mpa) using an Instron machine. He found that the intracanal placement of calcium hydroxide weakened the MTFS of teeth by 13.9 Mpa per 77 days: an average of 0.157 MPa $day)^{-1}$. The MTFS of the dentin was reduced by 43.9% between 7 and 84 days. This difference was statistically significant ($P < 0.05$). The weakening of the dentin by 23–43.9% following root canal filling with calcium hydroxide provides compelling evidence to re-evaluate the daily usage of this material in endodontic therapy. [38]

R Pace (2007) in his study observed the clinical and radiographic findings of teeth that suffered premature interruption of root development and treated by a mineral trioxide aggregate (MTA) apical plug technique and concluded orthograde MTA plugs placed by hand under microscopic vision resulted in a successful outcome at 2 years. Radiographic and clinical healing occurred in about 10 out of 11 teeth. [39]

Zahed Mohammad (2008) evaluated the sealing ability of grey-coloured mineral trioxide aggregate (GMTA), white-coloured MTA (WMTA), and gutta-percha+AH-26 sealer as root filling materials and concluded GMTA and WMTA can be recommended as orthograde root filling materials. [40]

David E. Witherspoon (2008) evaluated the outcome of nonsurgical root canal treatment of teeth with open apices obturated with mineral trioxide aggregate. One hundred sixteen patients from a single private endodontic office were treated between 1999 and 2006. 144 teeth were successfully treated either in one (92/144) or two visits with calcium hydroxide interappointment medication (52/144). 54% of the teeth were recalled (60.3% one visit and 39.7% two visits). The maximum time to recall was 4.87 years. The mean time to recall was 19.4 months. 93.5% of teeth treated in 1 visit healed, and 90.5% of teeth treated in 2 visits healed in one-year recall period. Finally, he concluded his study saying MTA obturation of canals with open apices is a viable alternative to the use of calcium hydroxide to induce apical closure. [41]

Arathi Rao et al (2009) in their review article on Mineral Trioxide Aggregate (MTA) stated that MTA is an excellent material with innumerable qualities required of an ideal material. One of the important applications of MTA in Pediatric Dentistry is in the management of non-vital immature teeth. Apexification with calcium hydroxide makes the tooth less resistant to fracture. Single visit MTA apical plug placement has proved to be a successful alternative in such cases. MTA is also successful in the formation of a dentin bridge that is thicker with lesser defects and side effects. MTA need to be explored by clinicians so that its beneficial properties can be extracted. [42]

Denise Pontes Raldi et al (2009) Reported three clinical cases involving teeth with open apices and apical periodontitis were treated using different protocols. The intracanal calcium hydroxide paste was placed for 12 months before obturation with gutta-percha and sealer. Mineral trioxide aggregate (MTA) apical plug was used before obturation with gutta-percha and sealer and treatment was completed in 2 appointments. Next, the root canal was completely obturated with MTA and treatment was completed in 2 appointments. In all 3 cases, signs of bone healing were observed after treatment. [43]

Safoora Sahebi et al (2010) evaluated the effects of a short-term use of calcium hydroxide on the compressive strength of dentine from mature human permanent teeth and concluded that 30 days of calcium hydroxide inside the root canal required less compressive force to break root dentin cylinders. It means that the short-term application of calcium hydroxide can reduce the dentin strength significantly. [44]

Masoud Parirokh and Mahmoud Torabinejad (2010) in their review on Mineral Trioxide Aggregate: A Comprehensive Literature Review—Part I: Chemical, Physical, and Antibacterial Properties concluded MTA is a bioactive material that influences its surrounding environment. [45]

Tina Rodig (2011) compared the efficacy of ultrasonic irrigation and RinsEndo in removing calcium hydroxide and Ledermix paste from simulated root canal irregularities and found none of the irrigation techniques completely removed the intracanal medicaments from the apical third of the root canal. Irrespective of the irrigation technique, significantly less Ledermix paste was detected compared with calcium hydroxide. [46]

Eun-Jung Shin et al (2011) investigated whether short-term application of calcium hydroxide in the root canal system for 1 and 4 wks affects the fracture strength of human permanent teeth and stated that the mean fracture strengths of two groups after 1 wk and 4 wks were similar. The fracture strength was reduced by 8.2% after 4 wk with the use of intracanal calcium hydroxide: an average of 39.23 MPa for no treatment group and 36.01 MPa for CH group. However, there was no statistically significant difference between experimental groups and between time intervals. [47]

Naiana Viana Viola (2011) reviewed literature related to MTA and PC comparing their physical, chemical and biological properties, as well as their indications and concluded stating that MTA and CP show promissory perspective both in Dentistry and Endodontics. [48]

Ronaldo Araújo Souza (2011) described a technique for maxillary right canine with an over instrumented apex, complete loss of the apical stop, extensive canal transportation and apical periodontitis. A 5 mm calcium hydroxide apical plug was placed before root canal filling and obturated with an inverted #80 gutta-percha cone and zinc oxide eugenol-based sealer by the lateral condensation technique. An 8-year radiographic follow-up showed formation of mineralized tissue sealing the apical foramen, apical remodeling and no signs of apical periodontitis. [49]

Beena.S and Chandrashekar.L (2011) reported a case on the clinical procedure used to produce a hard tissue barrier in the open apex, and onto which gutta percha along with the sealer was condensed by a special custom-made technique. [50]

M. Giovarruscio et al (2012) placed Mineral trioxide aggregate (MTA) apical plugs in canals with wide apices and concluded that the adoption of de-sheathed Thermafil carriers as flexible MTA pluggers provides improved control and consequently a reduced risk of MTA extrusion in cases of canals with wide apices. [51]

Mohammed Mustafa et al (2012) reviewed calcium hydroxide as a multipurpose agent, including inter-appointment intracanal medicaments, endodontic sealers, pulp capping agents, apexification, pulpotomy and weeping canals. The purpose of their article is to review the properties, advantages, disadvantages and various indications for the use of calcium hydroxide in endodontics. [52]

Tania Afonso et al (2012) evaluated the effect of calcium hydroxide premedication on the apical seal of White MTA, placed as an apical barrier in permanent teeth with simulated immature apices and compared potential changes, under the influence of calcium hydroxide, in the apical seal of MTA over time and it was concluded that intracanal medication with calcium hydroxide did not affect the sealing ability of WMTA, placed as an apical plug, neither on the 7**th** nor on the 28**th** day.[53]

Allen N. Sawyer (2012) conducted a study on whether prolonged contact of dentin with Calcium Silicate-based Materials adversely affects its mechanical properties and concluded that both Calcium Silicate-based Materials alter material toughness more than the strength and stiffness of dentin after aging in 100% relative humidity. [54]

Anderson de Oliveira Paulo et al (2013) reported a case of Oehlers' Type 1 dens invaginatus in an immature permanent maxillary right lateral incisor, which presented pulp necrosis secondary to trauma that was treated by apexification with white MTA followed by conventional root canal therapy. They concluded that use of MTA with appropriate instrumentation and obturation techniques, make this material an excellent option in the endodontic therapy of immature permanent teeth with dens invaginatus.[55]

Murugesan Gawthaman et al (2013) reported a case series wherein calcium hydroxide and MTA were used successfully for one step apexification in teeth with open apex and stated that apexification procedure can be done with both MTA and calcium hydroxide. Considering the time duration for the apex closure MTA has superior properties when compared with calcium hydroxide. [56]

G. H. Yassen et al (2013) investigated the effect of medicaments used in endodontic regeneration on root fracture resistance and microhardness of radicular dentine and stated that the 3-month application of triple antibiotic paste, double antibiotic paste or calcium hydroxide paste medicaments significantly reduced the root fracture resistance of extracted teeth compared to a 1-week application. [57]

Ga-Yeon Jang et al (2013) investigated the effects of root canal irrigants on the washout resistance of Endocem in compared to ProRoot MTA in a furcal perforation model and concluded that Our results indicate that Endocem exhibited superior washout resistance compared to ProRoot, and Endocem may be considered a substitute for ProRoot in a single-visit scenario of conventional root canal treatment. [58]

Ji-Hyun Jang et al (2013) evaluated the crown discoloration with the use of mineral trioxide aggregate (MTA) and examined the effect of internal bleaching on discoloration associated with MTA and stated that ProRoot and Angelus caused tooth discoloration. However, Endocem did not affect the contacting dentin surface. [59]

Yoorina Choi et al (2013) evaluated the biological effects of a newly developed fast-setting, mineral trioxide aggregate– derived pozzolan cement (Endocem) and the results suggested that Endocem can be used as an available retrograde filling material because it sets faster and shows similar biological effects when compared with ProRoot. [60]

Seok-Woo Chang et al (2013) reported one-step apexification using Mineral Trioxide Aggregate (MTA) as an alternative treatment modality with more benefits than the use of long-term calcium hydroxide for teeth with open apex. [61]

Divya D et al (2014) reviewed Root end Filling materials and stated that an ideal root end filling material should be non-toxic, biocompatible, non-resorbable, dimensionally stable and produce a fluid tight seal and have revealed that MTA and super EBA are superior to other retro-grade filling materials. [62]

Nirav J.Parmar et al (2014) reviewed Root end filling materials and stated that there is no existing retrofilling material possess all the ideal characteristics of a retro fill material. MTA, CPC and COP have shown promising results. [63]

Su-Jung Park et al (2014) investigated the odontogenic effects of Fast-setting Pozzolan cement in vitro and in vivo and indicated that ProRoot and Endocem have similar biocompatibility and odontogenic effects. Therefore, Endocem is as effective a pulp capping material as ProRoot. [64]

Miri Kim et al (2014) compared the Ortho MTA and Endocem MTA with those of ProRoot MTA with respect to their biologic properties using the preosteoblast like cell line MC3T3-E1. Pro-Root MTA was found to be better than Ortho MTA and Endocem MTA. [65]

Minju Song et al (2014) evaluated the cytotoxicity of the pozzolan cement with other root-end filling materials using human periodontal ligament cell and concluded that the cytotoxicity of the pozzolan cement was comparable with ProRoot MTA and Angelus MTA. Considering the difficult manipulation and long setting time of ProRoot MTA and Angelus MTA, Endocem can be used as the alternative of retrofilling material. [66]

L.Han et al (2015) evaluated the release of calcium ions from Endocem MTA and Endocem Zr to produce apatite-like precipitates after immersion in phosphate-buffered saline (PBS). Endocem MTA and Endocem Zr showed significantly less Ca ions when compared to white MTA release and when immersed in Phosphate

Buffered Saline, apatite-like crystalline precipitates were produced that significantly reduced Ca/P ratio.[67]

Maura Cristiane Gonçales Orçati Dorileo et al (2014) compared physicochemical properties of pozzolan Portland cement to ProRoot MTA and MTA BIO and stated that only the MTA-based cements met the ANSI/ADA recommendations for radiopacity. They concluded that pozzolan Portland cement are similar to and comparable to those of MTA-based cements. [68]

Murvindran.V and James.D.Raj (2014) in their review article on Antibiotics as an intracanal medicament in endodontics stated that the evidence shows that mechanical instrumentation, irrigation and use of inter appointment medication were all important in this regard. However, all of the currently available antimicrobial materials for root canal irrigation and medication have limitations, and the search continues for the ideal irrigant and interappointment medicament. [69]

M. Kundabala et al (2014) presented clinical study to investigate the effectiveness of Ledermix paste as an intracanal medicament in symptomatic teeth using the eugenol as control. Access was gained for 30 symptomatic teeth, Intracanal medicament was placed. Incidence of pain and tenderness after access opening were evaluated. Ledermix was appreciated to have better and faster action than eugenol in reducing symptoms i.e. within 72 hrs. [70]

Revathi. N and Sharath Chandra S (2014) in their literature review on merits and demerits of Calcium hydroxide stated that the applications of Calcium hydroxide in dentistry is innumerable. The high alkaline nature has contributed to its antimicrobial and hard tissue forming properties. However, the lack of effectiveness against certain bacteria, solubility in fluids, poor coronal seal and strength are some concerns that need to be addressed. [71]

Sanjana A Patil et al (2014) presented case reports on the short-term follow-up results in two treated teeth with non-vital pulps and open root apices which were managed with MTA apical plug technique, placed under the operating microscope and stated that apexification in one visit, by placing an apical plug of MTA, is a predictable and reproducible clinical procedure. [72]

AC Bhuyan et al (2015) evaluated the effectiveness of different techniques in removing calcium hydroxide $Ca(OH)_2$ from the root canal and concluded that none of the techniques used were completely able to remove $Ca(OH)_2$ from the root canals. But the Canal brush and ultrasonic techniques were significantly better than the rotary instrument and irrigant groups. [73]

Nikhil Vineeta et al (2015) compared the aqueous-based calcium hydroxide and oil-based calcium hydroxide removal with the use of two different chelators 17% EDTA and 0.2% Chitosan in combination with ultrasonic agitation and concluded that $Ca(OH)_2$ remnants were minimal in canals irrigated with 0.2% Chitosan in combination with ultrasonic agitation than 17% EDTA irrespective of type of vehicle present in the mix.[74]

Sehnaz Yilmaz et al (2015) evaluated the effect of various endodontic regeneration agents on the microhardness of human root dentin after contact for various time intervals and concluded that applying Double Antibiotic Paste (DAP) and Triple Antibiotic Paste (TAP) for 4 weeks significantly reduced the microhardness values of dentin discs compared with the baseline values. [75]

Ghaeth Hamdon Yassen et al (2015) investigated the effects of different intracanal medicaments on chemical structure and microhardness of dentin and stated that the use of methylcellulose-based triple antibiotic paste or $Ca(OH)_2$ medicaments significantly reduced microhardness and superficial demineralization of dentin in regenerative procedures compared to the use of triple antibiotic paste (TAP).[76]

Tugba Turk and Ales Fidler (2015) evaluated the effect of the intracanal medicaments used in regenerative endodontic treatment on push-out bond strength (PBS) of mineral trioxide aggregate (MTA) and Biodentine (BD) and concluded the study stating that antibiotic medications seemed to decrease the dentin resistance of MTA and BD after a two-week application period. [77]

Elgendy and MM Nagy (2015) investigated the fracture resistance of radicular dentin by Propolis compared to Triple antibiotic paste and Chlorhexidine and concluded that Propolis and TAP when used as intracanal medicaments adversely affects fracture resistance compared to Chlorhexidine. Chlorhexidine intracanal medication is considered safe regarding the fracture resistance of root canal dentin. [78]

E. Nagas et al (2015) evaluated the effect of prior application of several intracanal medicaments on the push-out bond strength of ProRoot MTA and Biodentine and concluded that the dislocation resistance of Biodentine (Septodont, Saint-Maur-des-Fosses, France) was less affected by prior medication with Augmentin (Champs Pharmacy), TAP or Ledermix (Riemser). However, for both Biodentine (Septodent) and MTA (Dentsply Tulsa Dental), prior medication with CH significantly improved the bond strength to root dentine. [79]

Babitaahlawat et al (2015) reported a case on apexification with rapid MTA plug technique apexification and stated that, with a novel biocompatible material like MTA is a new boon in effective management of teeth with open apex. [80]

Alejandra Citlalli Rodríguez Rocha et al (2015) compared the properties of both MTA Angelus® White (Angelus Lodrina, Parana Brazil) and Biodentine (Septodont, Saint-Maur-des Fosses, France) and concluded that MTA Angelus was comparable to Biodentine, except the radiopacity, the grain shape and size, presence of calcium chloride that is present in the chemical composition of Biodentine. [81]

Peter Z Tawil et al (2015) in their scientific research has demonstrated the effectiveness of traditional MTA when used in a range of endodontic procedures and when sealing effectiveness and biocompatibility are considered, there is no other dental material on the market similar to MTA. With the recent introduction of a fast setting MTA which also offers excellent handling properties. [82]

Abhijeet Kamalkishor Kakani et al (2015) reported a case of complete healing of a periapical abscess after placement of MTA apical plug, after the root canals were debrided and rinsed with Sodium hypochlorite. The remaining portion of the root canal was obturated using lateral condensation technique, and a crown was placed. After 6 months of follow-up complete healing of the periapical lesion was noticed this was evident radiologically. This case report suggests that use of MTA as an apical sealing material is a significant alternative to the conventional methods of apexification. [83]

Raidan Ba-hattab et al (2016) reviewed calcium hydroxide used in endodontics, concentrating on its mechanism of action, antimicrobial effects, their applications, cytotoxicity and their removal from the root canals. [84]

Emmanuel Joao Nogueira Leal Silva et al (2016) investigated the root canal dentin bond strength of 2 newly developed fast setting Mineral Trioxide Aggregate (MTA) and pozzolan-based cements: Endocem MTA (Maruchi, Wonju, Korea) and Endocem Zr (Maruchi). White MTA (Angelus, Londrina, Brazil) was used as the reference material for comparison and concluded that the new fast-setting MTA and pozzolan-based cements Endocem MTA and Endocem Zr present suitable bond strength performance, which is comparable with white MTA. [85]

BS Keshava Prasad and Chitra T Naik (2017) reviewed Mineral trioxide Aggregate in endodontics and stated that the use of MTA for pulp capping, pulpotomy, apical barrier formation in teeth with open apices, repair of root perforations and root canal filling has been known. Studies that have been previously published signifies that MTA has been successfully used for one visit apexification.[86]

Ersan Cicek et al (2017) compared the fracture resistance of simulated immature teeth after using different thicknesses of Mineral Trioxide Aggregate (MTA) apical plugs and concluded that MTA should be used as an apical plug instead of root canal filling material to increase the fracture resistance of immature teeth. [87]

Negin Ghasemi et al (2017) conducted a study was to measure the voids in the apical plug with the use of the CBCT technique and concluded that use of ultrasonic mixing and manual placement techniques resulted in a decrease in the number of voids in the apical plug. [88]

A.Agrafioti et al (2017) shortlisted the studies with regards to apexification and artificial apical barrier techniques, and investigated the differences of the clinical procedures and how these evolve over time and stated that both clinical techniques lead to favourable outcomes. [89]

Mohammadreza Nabavizadeh et al (2017) evaluated the effect of calcium hydroxide, double and triple antibiotic paste on the sealing ability of Mineral Trioxide Aggregate (MTA) apical plugs and concluded that there is only short-term effect with the use of TAP and calcium hydroxide as intra-canal medicaments on the microleakage of MTA plugs. All of the medicaments tested in this study can be used without any concern about permanent changes in the microleakage of MTA. [90]

Merve Nur Aydin and Burak Buldur (2017) evaluated the effect of intracanal placement of various medicaments on the bond strength of ProRooT MTA, Biodentine, and Endosequence root repair material (ERRM) putty and concluded that intracanal placement of DAP and TAPs decreased the bond strength of calcium silicate-based cements to dentin, CH and Augmentin® had no effect. [91]

CH Jonker and PJ van der Vyver (2017) reported cases on Apexification of immature teeth using an apical matrix and MTA barrier material and concluded that apexification with the use of MTA in management of teeth with incomplete root formation provides an excellent treatment option and has the advantage of reduced chair time. [92]

Kanchan Bhagat et al (2017) in their review article on root end filling materials and recent advances and said that earlier amalgam was considered the material of choice but recently MTA has been developed which fulfils almost all the requirements of an ideal root end filling material and compared their biocompatibility, sealing ability, anti-bacterial effects and microleakage. [93]

Mandeep Kaur et al (2017) evaluated MTA versus Biodentine: Review of literature with a comparative analysis compared the properties of MTA and Biodentine. Due to lack of long-term observational studies, it is difficult to infer concretely that which material out of MTA and Biodentine is superior, however, physical properties and economical factors fall in favour of Biodentine.[94]

Ivan Matović et al (2018) conducted a study on the application of MTA as apical plug for root canal obturation – in vitro study and assessed the quality of root canal obturation using gas (Argon) penetration method when MTA is used as an apical plug. He concluded that root canal obturation demonstrated significantly lower gas penetration with the group obturated with different sealers, gutta-percha and MTA apical plug compared to traditional technique that is obturated with gutta-percha and sealer without MTA plug. [95]

Pradnya V. Bansode et al (2018) reviewed newer modification 'Pozzolan Dental Cement' which has been evaluated and compared with the existing tricalcium silicate-based cement and said that Pozzolan based dental cements may serve as a promising alternative to other Tricalcium Silicate based Cements in the near future because of its enhanced or comparable properties in most of the aspects. [96]

Elif Aybala Oktay et al (2018) evaluated the effect of intracanal medicaments used in endodontic regeneration on the push-out bond strength of a calcium phosphate-silicate-based cement to dentin and concluded that the push-out bond strength of ERRM to root dentin is significantly higher when CH is used as an intracanal medicament as compared to an intracanal medicament containing antibiotics. These findings suggest that the use of CH in clinical practice may help improve the adhesion of calcium phosphate silicate cement to dentin. [97]

Suzan Abdul Wanes Amin and Shaimaa Ismail Gawdat (2018) compared the retention of coronal plugs of BioAggregate (BA; Innovative Bioceramix) and mineral trioxide aggregate (MTA; Angelus) in the root canal wall after treated with different intracanal medications (ICM) used in endodontic regeneration. He concluded that MTA shows better retention as a coronal plug than BA, but the BA failure mode is more likely to be cohesive than adhesive. BA retention is less affected than MTA retention by the different types of ICM used in REP. CH seems to improve the bond of MTA to dentin as a coronal plug. BA may be considered as an alternative coronal plug material in REP. [98]

Madhumitha Jayakumar et al (2018) in their article MTA: A review of literature with clinical applications and demonstrated the effectiveness of MTA when used in a range of endodontic procedures. MTA has numerous qualities as an ideal bioactive material. Also, they have discussed the properties, sealing ability, setting reaction, biocompatibility and clinical performance of MTA. Considering the sealing effectiveness and biocompatibility, MTA cannot be compared to any other dental material. [99]

Kadriye Demirkaya et al (2018) investigated and compared the composition and micro surface structure of two different calcium silicate–containing filling materials using energy dispersive X-ray spectroscopy (EDX) and scanning electron microscopy (SEM). He concluded that the mineralogical composition of BioAggregate was different from that of MTA Angelus. BioAggregate did not contain tricalcium aluminate phase as compared to MTA and it included tantalum oxide as a radiopacifier. SEM images of MTA Angelus represented a more porous surface structure than that of BioAggregate. [100]

Luiz Alexandre Chisini et al (2018) compared the clinical outcomes of MTA apical plug apexification or revascularization both clinically and radiographically in Necrotic Immature Permanent Teeth and concluded that Apexification with the barrier technique using MTA-apical plug provides similar clinical success rate than revascularization. [101]

MATERIALS AND METHODS

Source of samples:

Ninety human anterior teeth extracted for periodontal reasons were collected from the Department of Oral and Maxillofacial Surgery, Vivekanandha Dental College for Women, Tiruchengode.

Materials used:

- Ledermix paste.
- Calcium hydroxide powder.
- Saline.
- 17% EDTA.
- Sodium hypochlorite.
- Distilled water.
- MTA (Angelus).
- Endocem MTA (Maruchi).
- Temporary restoration.

Armamentarium:

- Slow speed latch type Micromotor hand piece (NSK).
- Endomotor (X-Smart).
- Ultrasonic unit (Woodpecker).
- X-Ray unit.
- Parallel post drill (1.25mm diameter).

- MTA Gun (GDC).
- Protaper universal files (Dentsply).
- Hand Plugger (GDC).
- X-Ray film (Carestream).
- Paper points (Dentsply).
- Ultrasonic U-Files (Woodpecker).
- Diamond disc.
- Incubator.
- Universal testing machine (Instron)

COMPOSITION OF ROOT-END MATERIALS USED IN THIS STUDY

S.NO	MATERIAL	MANUFACTURER	COMPOSITION
1.	Angelus MTA	Angelus, Solucoes Odontologicas, Lonrina, Brazil.	**Powder**: Portland cement* + Bismuth oxide + Gypsum. **Liquid:** Distilled water/PBS. ***Portland cement** – Dicalcium silicate, Tricalcium silicate, Tricalcium aluminate, Tetracalcium aluminoferrate, Calcium sulfate.
2.	Endocem MTA	Maruchi, Wonju, Korea.	**Powder:** MTA+ small particle Pozzolan cements* **Liquid:** Distilled water/PBS. ***Pozzolan cement** – silicon/Silicon-aluminium (having no initial binding capacity itself, later when the water is added they set into hydraulic cement)

Method of collection of samples:

Ninety human anterior teeth extracted for periodontal reasons were collected from the Department of Oral and Maxillofacial Surgery, Vivekanandha Dental College for Women, Tiruchengode, and stored in formalin.

Infection Control protocol for the teeth collected for this study:

Occupational Safety and Health Administration (OSHA) and Centre for Disease Control & Prevention (CDC) guidelines for collection, storage and handling of extracted teeth samples are:

1. Handling of teeth was always done using gloves, mask and protective eyewear.

2. Teeth were cleaned of any visible blood and gross debris.

3. Distilled water was used in wide mouth plastic jars for initial collection.

4. Teeth were immersed in 10% formalin for 7 days, following which the liquid was discarded and the teeth were transferred into separate jars containing distilled water.

5. The initial collection jars, lids and the gloves employed were discarded into biohazard waste receptacles.

6. As and when the teeth were required, they were removed from the jars with cotton pliers and rinsed in tap water.

Exclusion criteria:

Roots with presence of cracks, caries or restorations were excluded from the study.

Inclusion criteria:

Intact Maxillary anterior teeth extracted for periodontal reasons were included.

PROCEDURE

Removal of external residual tissues:

The selected teeth were stored in 10% formalin following extraction and calculus was mechanically removed using hand scalers.

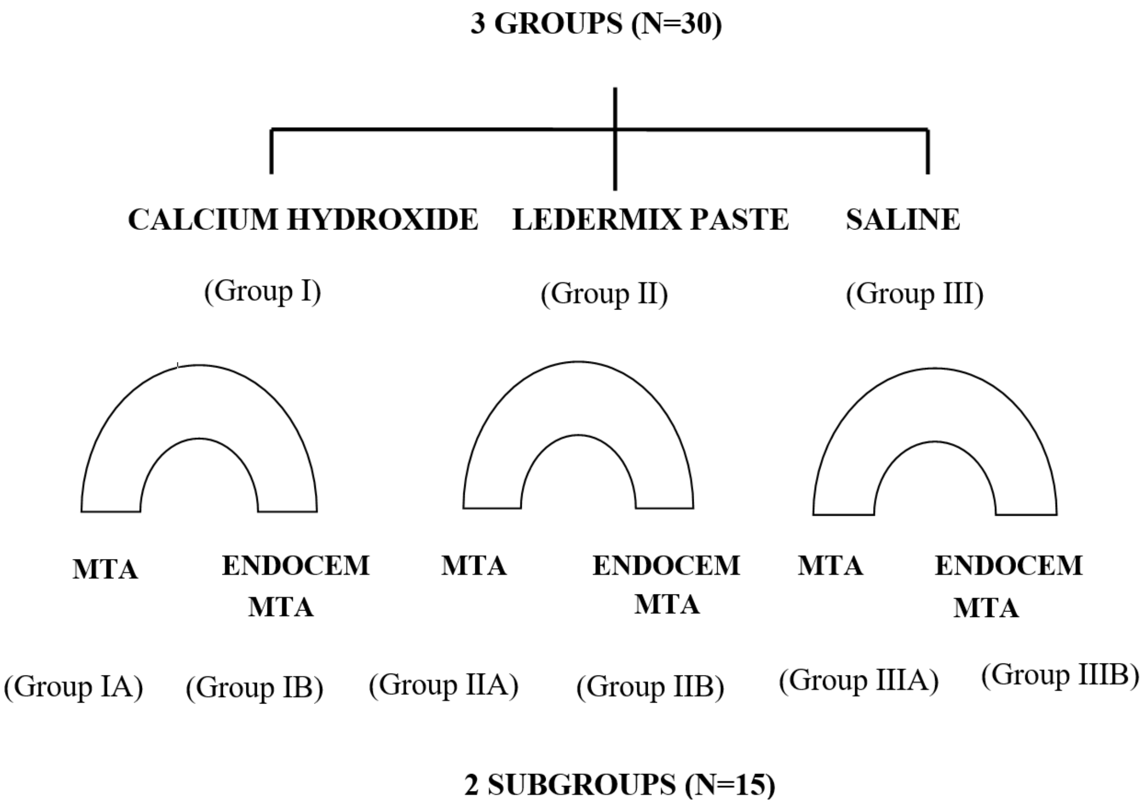
Procedure:

Ninety freshly-extracted human maxillary anterior teeth with single and straight roots were selected. The crowns were decoronated below the cementoenamel junction and the length was adjusted to approximately 12mm (Fig.7). A parallel post drill (1.25 mm diameter) (Coltène/Whaledent, Summit County, OH, USA) was used to create a standardized parallel canal space of 1.25 mm diameter and 10 mm length (Fig.8). The root canals were cleaned and shaped with ProTaper files (Dentsply Tulsa Dental, Tulsa, OK, USA) up to size F5 (Fig.11), in conjunction with 2 mL of 5.25% Sodium hypochlorite between each file size. The canals were irrigated with 5 mL of Sodium hypochlorite for 5 min followed by 5 mL of 17% Ethylenediaminetetraacetic acid (EDTA) for 5 min to remove the smear layer (Fig.12). Finally, the specimens were irrigated with 10 mL of distilled water to avoid the prolonged effects of EDTA and Sodium hypochlorite. The root canals were subsequently dried with paper points. Then the specimens were randomly assigned into **3 groups** with respect to the use of intracanal medicaments (Fig.1, Fig.2, Fig.3):

GROUP (n=30/group)	INTRACANAL MEDICAMENT USED
Group 1	Calcium hydroxide with distilled water
Group 2	Antibiotic + Steroid paste
Group 3	Saline (control)

SUBGROUP (n=15)	ROOT-END FILLING MATERIAL
Subgroup 1	MTA
Subgroup 2	Endocem MTA

SAMPLE DISTRIBUTION N=90 samples



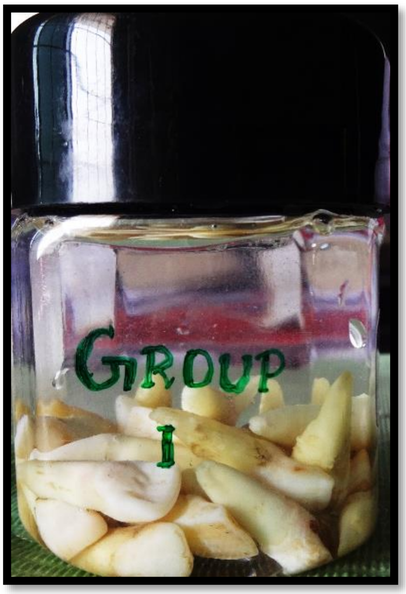
The intracanal medicaments were placed into the root canal with the Lentulo spirals (35 size) (Fig 13, Fig.14). And then the orifices were sealed with a cotton plug topped with Intermediate restorative material (IRM) (Fig.15). The specimens were stored for 2 weeks in 100% humidity at 37^0C, after the incubation period the intracanal medicaments were removed by irrigating with 5 mL of Sodium hypochlorite in conjunction with Ultrasonic U-Files (Fig.17), followed by a final flush of 5 mL of EDTA. The root canals were subsequently dried with paper points. The specimens were divided into **2 subgroups** according to the root-end filling applied:

The materials were mixed according to the manufacturer's instructions and placed into the root canal with MTA carrier (Fig.18) and compacted with a hand plugger (Fig.19), to create an Apical plug of 5mm thickness at the root apex and were confirmed with the radiograph (Fig.20). The root canal orifices were sealed with a cotton plug topped with IRM. The specimens were stored in 100% humidity at 37^0 C for 1 week. Each root was sectioned perpendicular to the long axis of the tooth in the apical third to obtain slices of 3mm thickness. The specimens were tested under the universal testing machine for assessment of push-out bond strength. (Fig.22) [79]

PUSH-OUT BOND STRENGTH TEST:

The specimens were subjected to load by using a 1mm-diameter custom stainless-steel cylindrical plunger mounted on a universal testing machine. The push-out force was applied in a cervico-apical direction at a crosshead speed of 1mm/min until the root filling material debonded. The load divided by area of bonded interface determines the bond strength failure calibrated in megapascals (MPa). The area in each section was calculated by using the following formula: Area = $2\pi r \times h$ (where π = constant value of 3.14, r=radius of the intraradicular space, and h=height in mm). [79]

DISTRIBUTION OF SAMPLES - GROUP I



PRE-OPERATIVE RADIOGRAPHIC EVALUATION - GROUP I

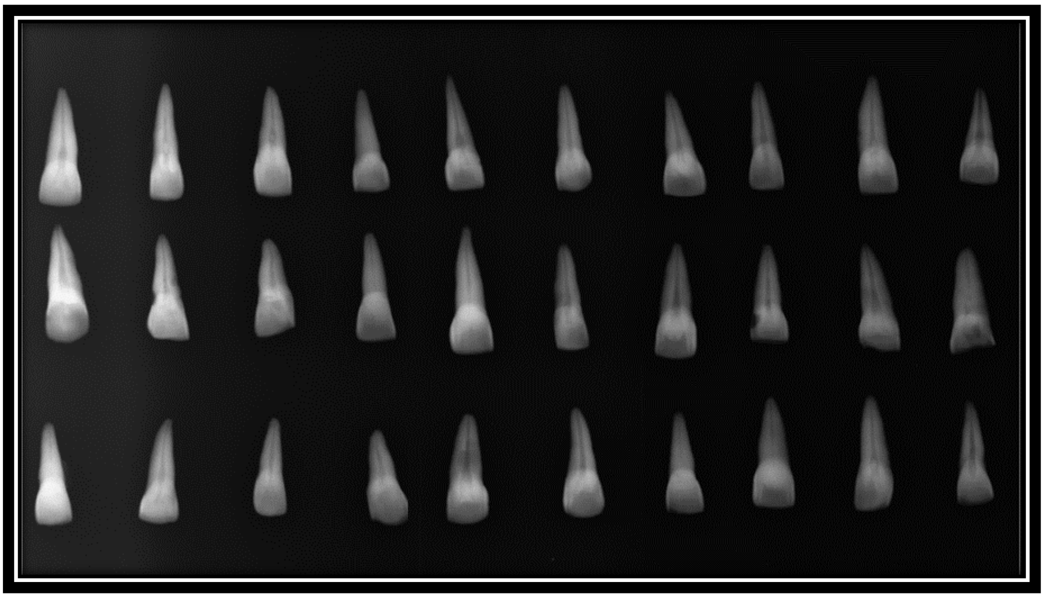
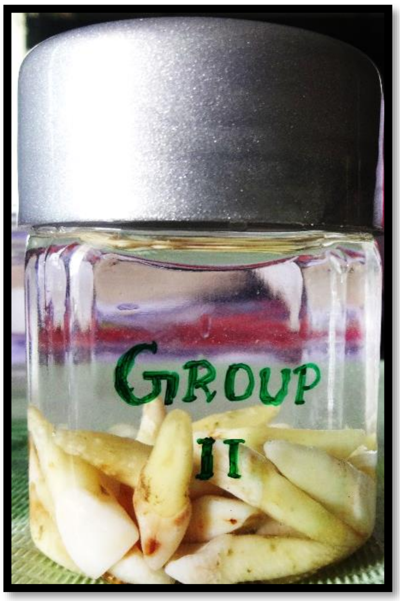


FIG:1 - GROUP 1

DISTRIBUTION OF SAMPLES - GROUP 2



PRE-OPERATIVE RADIOGRAPHIC EVALUATION – GROUP 2

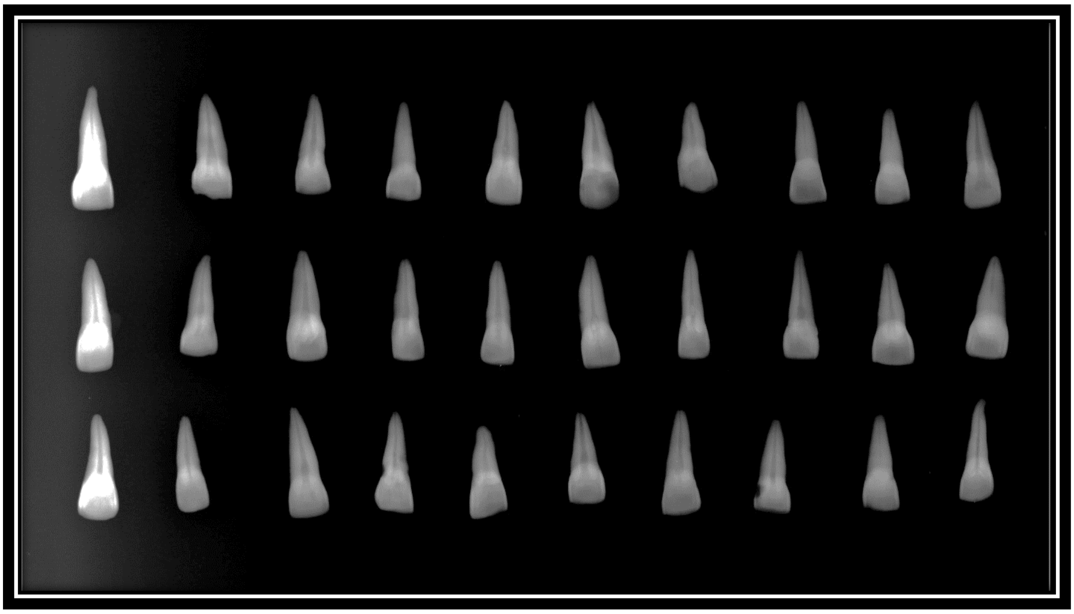
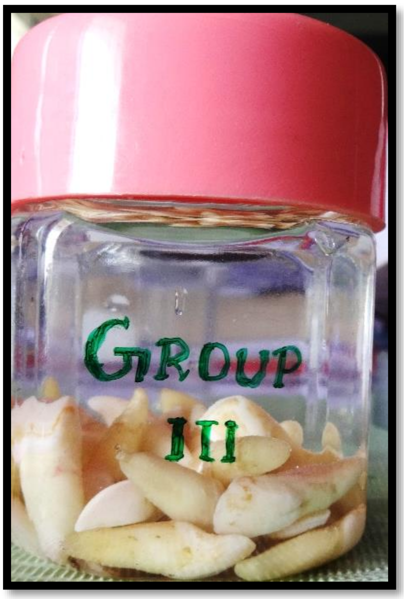


FIG:2 – GROUP 2

DISTRIBUTION OF SAMPLES - GROUP 3



PRE-OPERATIVE RADIOGRAPHIC EVALUATION – GROUP 3

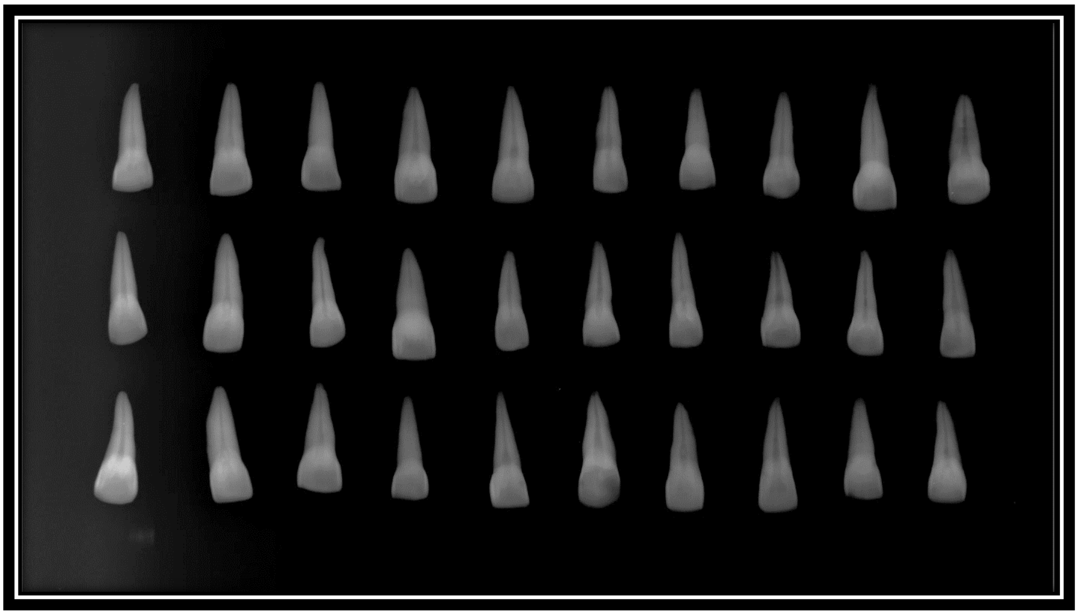


FIG:3 – GROUP 3

FIG:4 - ARMAMENTARIUM

FIG:5 - MATERIALS USED

FIG:6 - DECORONATION OF SAMPLES WITH DIAMOND DISC

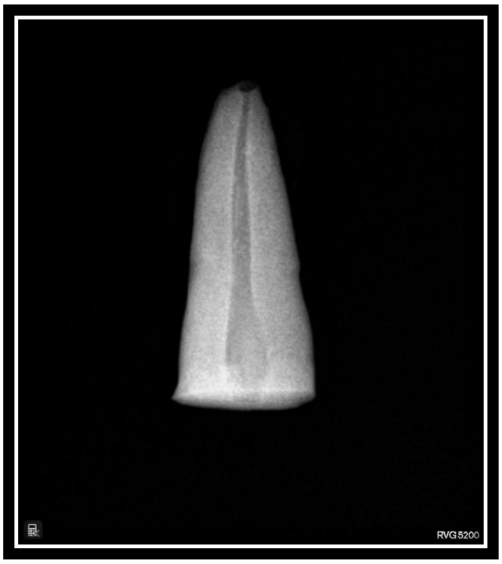


FIG:7 - DECORONATED TOOTH ON RADIOGRAPH

FIG:8 - OPEN APEX PREPARATION WITH PARALLEL POST DRILL

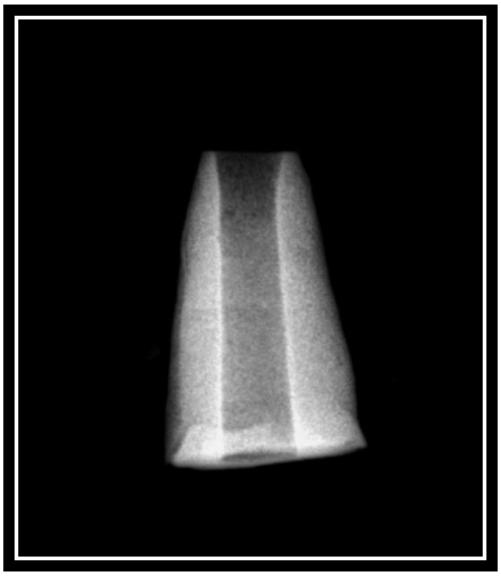


FIG:9 - OPEN APEX VERIFIED WITH RADIOGRAPH

A. CORONAL VIEW

B. APICAL VIEW

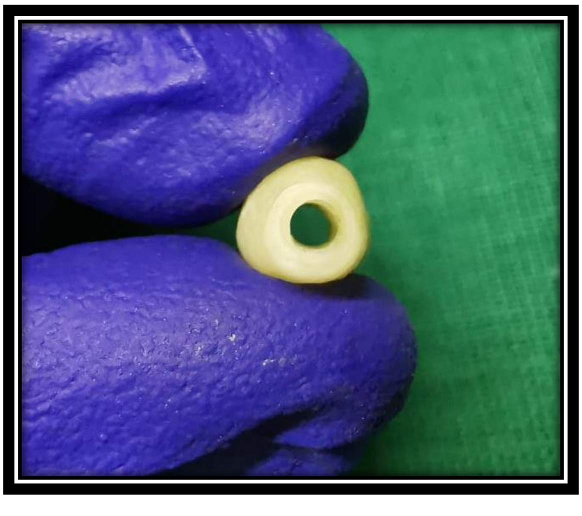
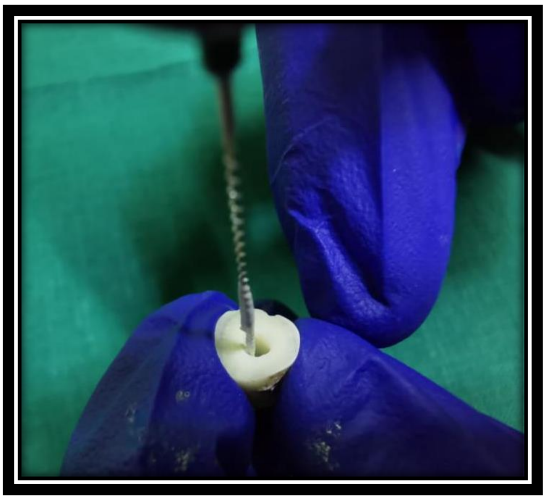


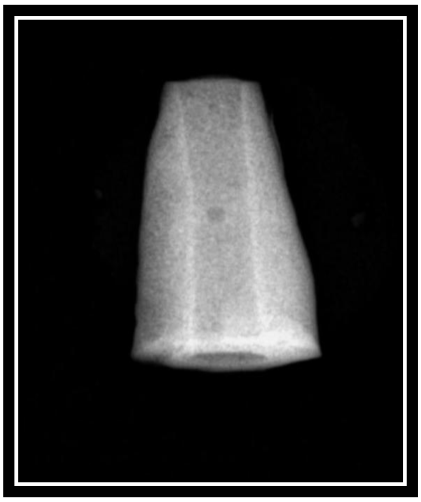
FIG:10 - PREPARED OPEN APEX FROM CEJ TO APEX

FIG:11 - CLEANING AND SHAPING OF ROOT CANAL

FIG:12 - ROOT CANAL IRRIGATION WITH SIDE VENTED NEEDLE



A i) CALCIUM HYDROXIDE POWDER WITH DISTILLED WATER



ii) CALCIUM HYDROXIDE POWDER ON RADIOGRAPH

FIG:13 – CALCIUM HYDROXIDE PLACED INTO ROOT CANALS WITH LENTULO SPIRALS

B. i) LEDERMIX PASTE

ii) LEDERMIX PASTE ON RADIOGRAPH

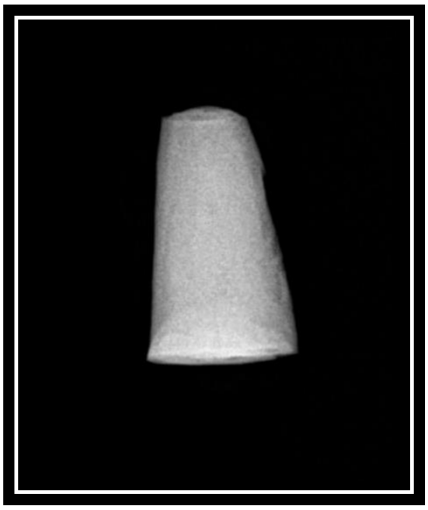


FIG:14 – LEDERMIX PASTE PLACED INTO THE ROOT CANAL WITH LENTULO SPIRALS

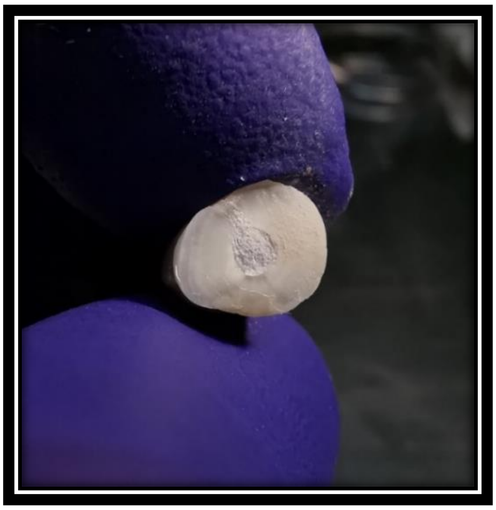


FIG:15 - ROOT CANAL ORIFICE SEALED WITH TEMPORARY RESTORATION

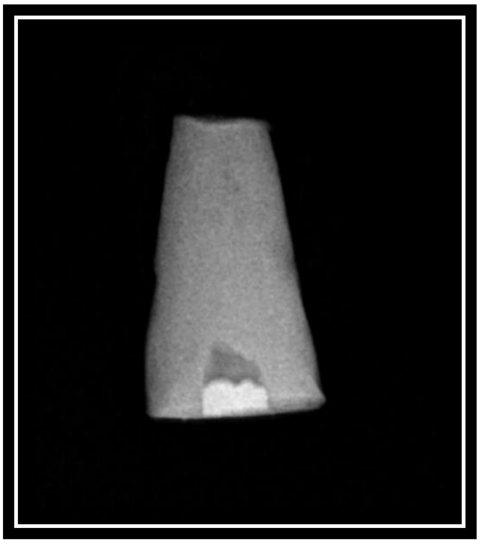


FIG:16 - RADIOGRAPH OF SEALED ROOT CANAL

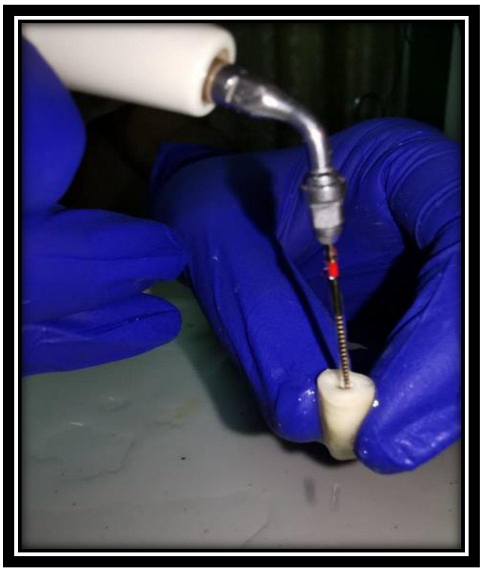


FIG:17 - INTRACANAL MEDICAMENT REMOVAL WITH ULTRASONICALLY AGITATED U-FILE

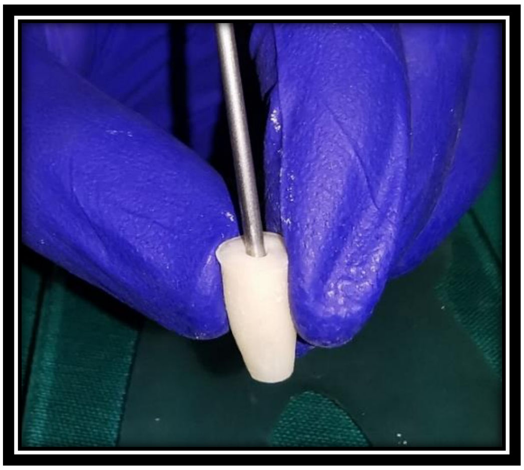


FIG:18 - MTA PLACED WITH MTA GUN

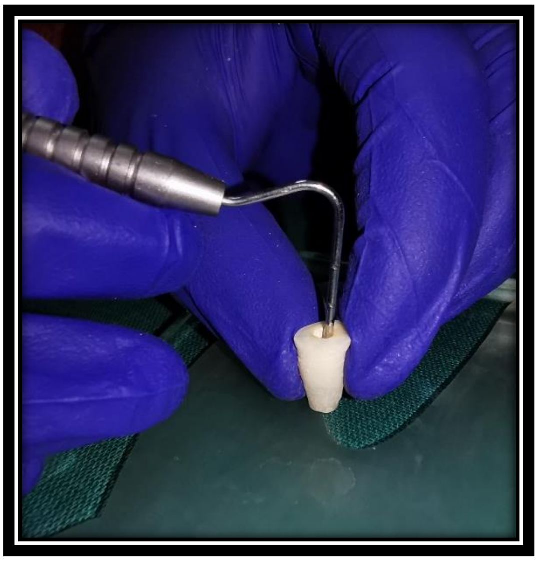


FIG:19 - MTA CONDENSED WITH HAND PLUGGER

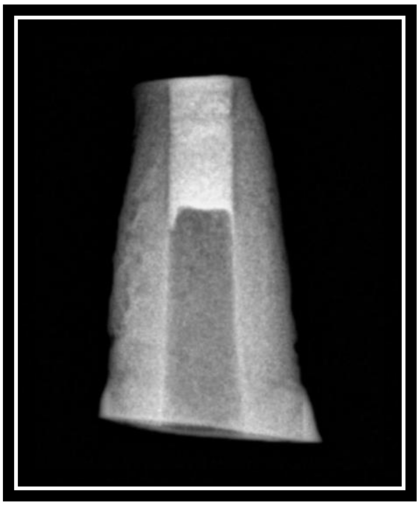


FIG:20 - APICAL PLUG VERIFIED WITH RADIOGRAPH

EXTRACTED NATURAL TOOTH WITH OPEN APEX

ARTIFICIALLY SIMULATED OPEN APEX

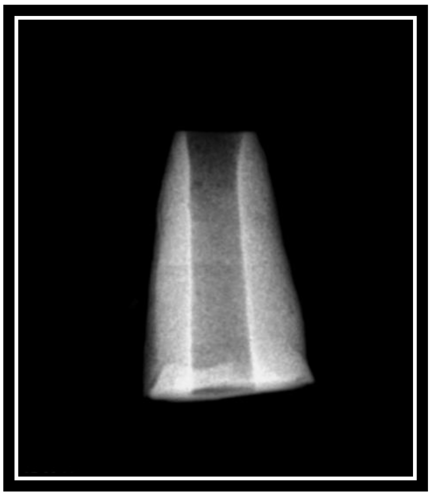


FIG: 21 – RADIOGRAPH OF REFERENCE TOOTH FOR OPEN APEX SIMULATION

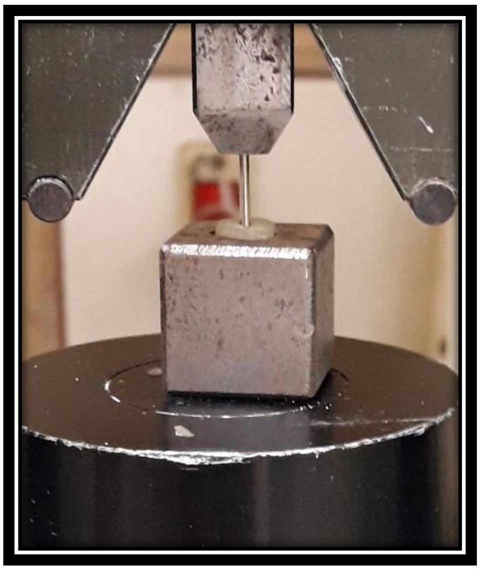


FIG:22 - SAMPLE TESTED UNDER UNIVERSAL TESTING MACHINE

RESULTS

In the present study, 30 samples of each group with the prior application of Calcium hydroxide, Ledermix paste, saline respectively was evaluated for the bond strength of MTA and Endocem MTA

Table 1: Mean difference in **push-out bond strength of MTA** with various intracanal medicaments

INTRACANAL MEDICAMENT	MTA (MEAN±S.D.)
Calcium Hydroxide (Group IA)	2.83±0.28
Ledermix paste (Group IIA)	2.36±0.14
Saline (Control) (Group IIIA)	2.61±0.24

Graph 1: Mean of push-out bond strength of MTA

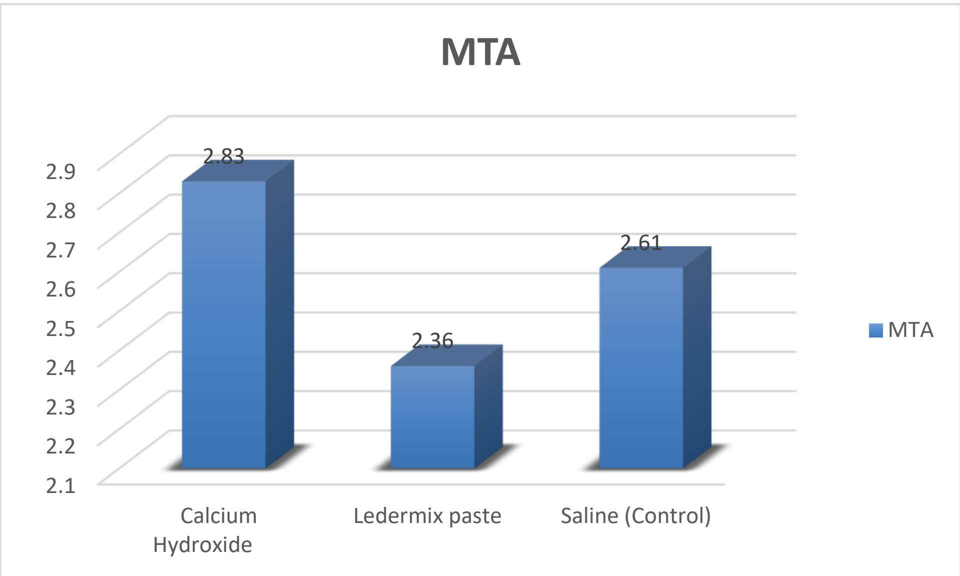


Table 2: Mean difference in **push-out bond strength of Endocem MTA** with various intracanal medicaments

INTRACANAL MEDICAMENT	ENDOCEM MTA (MEAN±S.D)
Calcium Hydroxide (Group IB)	3.02±0.16
Ledermix paste (Group IIB)	2.57±0.29
Saline (Control) (Group IIIB)	2.75±0.14

Graph 2: Mean push-out bond strength of Endocem MTA

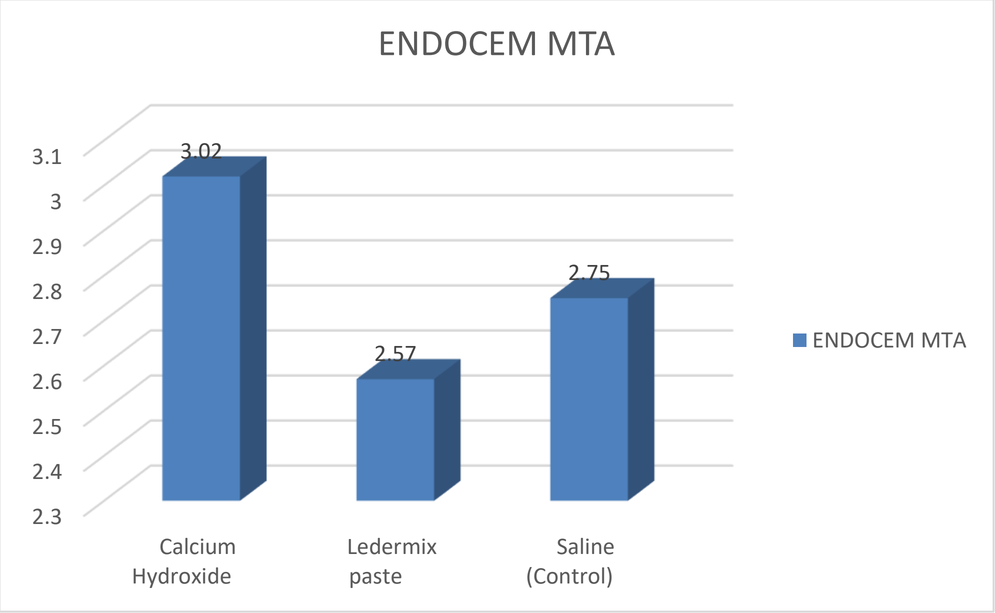


Table 3: Mean difference in push-out bond strength of all the three groups

INTRACANAL MEDICAMENT	ROOT END MATERIAL	MEAN±SD
Calcium Hydroxide (Group IA)	MTA	2.83±0.28
Calcium Hydroxide (Group IB)	Endocem MTA	3.02±0.16
Ledermix paste (Group IIA)	MTA	2.36±0.14
Ledermix paste (Group IIB)	Endocem MTA	2.57±0.29
Saline (Control) (Group IIIA)	MTA	2.61±0.24
Saline (Control) (Group IIIB)	Endocem MTA	2.75±0.14

Graph 6: Graphical presentation of push-out bond strength comparing all the three groups

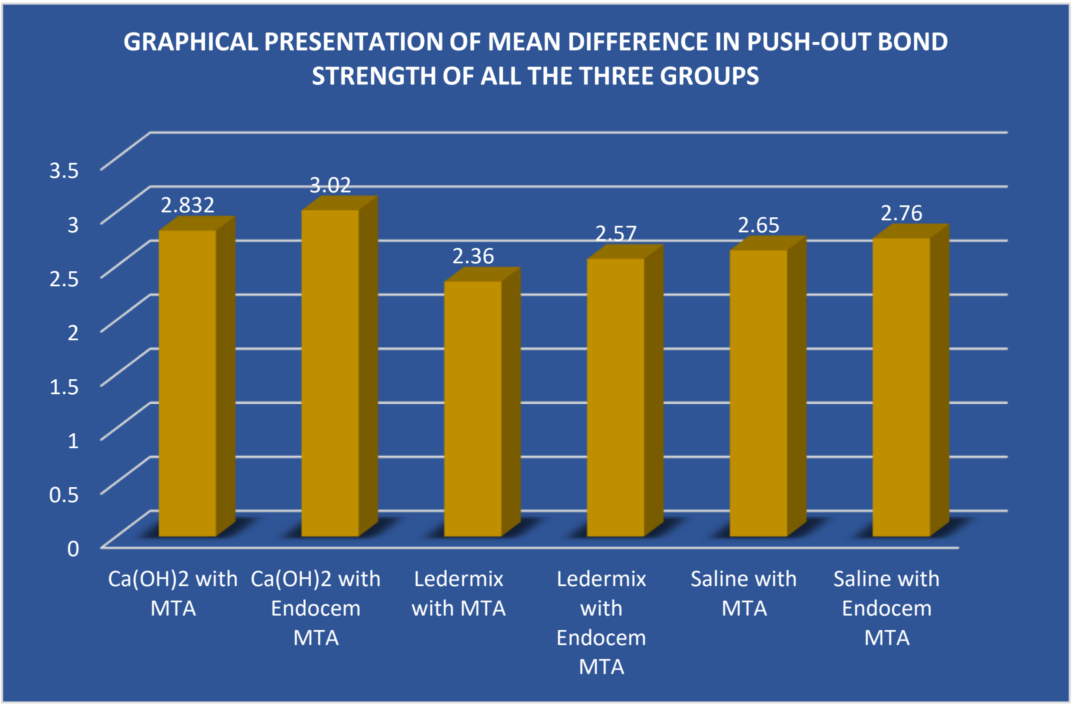


Table 4: Comparison within the two groups using Student paired t-test

INTRACANAL MEDICAMENT	ROOT-END FILLING	MEAN	SD	T VALUE	P VALUE	OBSERVED	0.95 C. I
Calcium Hydroxide	MTA	2.832	±0.28	-2.29	0.014*	2.832	±0.159
Calcium Hydroxide	Endocem MTA	3.029	±0.16			3.029	±0.093
Ledermix paste	MTA	2.363	±0.14	-2.46	0.01*	2.363	±0.082
Ledermix paste	Endocem MTA	2.572	±0.29			2.572	±0.162
Saline (Control)	MTA	2.605	±0.24	-2.06	0.024*	2.605	±0.134
Saline (Control)	Endocem MTA	2.755	±0.15			2.755	±0.079

*P value < 0.05 significant

Table 5: Comparison between the groups using one-way analysis of variance

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	P VALUE
Between Groups	4.004	5	0.801		
Within Groups	3.989	84	0.047	16.885	0
Total	7.993	89			

Multiple comparison between the study groups and within the groups was done using one-way Anova. (Table 5). The inference was statistically significant ($p<0.05$) pertaining to the push-out bond strength under the Universal testing machine.

The statistical analysis of the present study showed that Endocem MTA with the calcium hydroxide intracanal medicament group showed higher bond strength followed by MTA with calcium hydroxide, followed by Endocem MTA and MTA with saline (control), which is followed by Endocem MTA with Ledermix intracanal medicament and MTA with the Ledermix group in the descending order respectively.

DISCUSSION

The immature permanent tooth with necrosed pulp poses a challenge for the endodontist due to several characteristic features such as incomplete root formation, resulting in unfavourable crown/root ratio; thin root dentinal wall; wide root canal space; apical root divergence with the loss of an apical constriction resulting in open apex. Apexification is considered to be the treatment option in teeth with necrotic pulps with open apices. [102]

Historically, calcium hydroxide has been the material of choice used to induce the formation of an apical hard tissue barrier before placing a long-term root filling.[103] Many studies have reported favourable outcomes when calcium hydroxide is used alone or in combination with other materials.[104] However, despite a long history of use in apical closure procedures, there are several problems relating to the use of calcium hydroxide for apexification which includes longer duration for closure of root apex, the number of intracanal "dressings", the role of infection and the long-term application of calcium hydroxide in fracture resistance of the open apex tooth. Depending on the study, barrier formation is reported to take anywhere from 3–24 months.[105]

The long treatment time and multiple visits not only reduces patient compliance and makes patient follow-up more difficult, but also increases the vulnerability of the coronal restoration and allowing the canals to become reinfected.[106] However, it has been reported that prolonged contact of tooth with calcium hydroxide may result in weakening of roots and resultant fracture of immature teeth.[107]

Because of these complications calcium hydroxide has been now replaced by Mineral Trioxide Aggregate (MTA). MTA apexification treatment can be completed in a single visit or in two or more visits with the use of Calcium hydroxide as intracanal medicament.[108]

Given its high success rate the treatment of choice for these cases has been considered the placement of a mineral trioxide aggregate (MTA) apical plug.[109] Before placing the MTA apical barrier, the manufacturer recommends the use of Calcium hydroxide for one week as intracanal dressing and its subsequent removal.[110] The use of calcium hydroxide has been considered an important step in the reduction of the intracanal microbial flora.[111] Because of the detrimental effects of an acidic pH, caused by the inflammation of periapical tissues, on various physical properties of MTA, it could be advisable to delay the placement of the MTA plug to a second session, using Calcium hydroxide as inter-appointment intracanal medication in order to achieve additional disinfection and neutralization of an acidic environment.[112]

Before placing the apical plug, the removal of Calcium hydroxide has been recommended to allow proper adhesion between the filling material and the root dentin.[113] However, it has been shown that complete removal of Calcium hydroxide from the root canal walls is very difficult to achieve if not impossible, at least with the techniques so far available.[114] It is because of this reason, the concern arises about the sealing ability of the MTA apical plug in the presence of the remaining calcium hydroxide which may consequently affect the results of the treatment.

The aim of this experimental *in vitro* study is to evaluate the influence of the intracanal medicament (Calcium hydroxide, Ledermix paste), applied as dressing over a period of 1 week, on the apical sealing of the apical barrier (MTA, Endocem MTA) placed in permanent teeth with simulated immature apices and to compare the push-out bond strength of MTA and Endocem MTA on the apical sealing of the plug under the influence of this dressing.

Calcium hydroxide has been used in endodontics for a variety of purposes. They have high alkaline pH in its pure form, and has a characteristic ability to stimulate matrix formation and mineralization, and also has antibacterial properties because of its alkalinity and are dependent upon the tissue to which they are applied.

Calcium hydroxide is often used as inter-appointment dressing and pulp capping material [115] providing antibacterial and hard tissue stimulation because of high alkalinity and favourable environment [116] It is widely used as both short-term and long-term intracanal dressings and has been included in some root canal sealers.[117] Its antimicrobial activity is another reason for its therapeutic success.[118] This antimicrobial action is dependent on its nature of hydroxide ion release from the calcium hydroxide compound and their diffusion through the dentin.[119] The long-term filling of root canals with calcium hydroxide is widely accepted, especially when treating young, immature traumatized teeth or teeth with large periapical radiolucent areas. In these cases, the calcium hydroxide may be used for a variety of time periods ranging from 2 to 3 months up to 2 or 3 years. The immature teeth where apexification is planned the long-term use of calcium hydroxide results in the formation of an apical hard tissue barrier prior to obturation.[120]

Ledermix paste contains an antibiotic, demeclocycline hydrochloride and a corticosteroid, triamcinolone acetonide in a ratio of (3.2:1) in a polyethylene glycol base. The Ledermix paste easily gets penetrated through dentinal tubules and cementum to reach the periodontal and periapical tissues.[121] Abbott *et al*. showed that the dentinal tubules supplied the active components majorly to the periradicular tissues, compared to the apical foramen. The concentration of demeclocycline within Ledermix paste itself (i.e., as it would be when placed within the root canal) is highly effective for the use as intracanal medicament against susceptible species of bacteria.[122]

MTA consists of tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide and bismuth oxide. Except for the presence of bismuth oxide MTA is similar to Portland cement in components. Bismuth oxide is added (17-18 wt.%) to improve the properties and the radiopacity.[123] The MTA particles are smaller and uniform in size [124] whereas the particle size of Portland cement varies in size. Though Bismuth oxide is said to improve the radio opacity, MTA-Angelus that contain less bismuth oxide compared to ProRoot MTA, is more radio opaque than Pro-Root MTA [125]. MTA are of two types- grey and white. The main difference in composition is the presence of iron, aluminium and magnesium oxides. Asgary et al claim that these oxides are present in less quantity in white MTA [126] while others claim total absence of these oxides in white MTA**.**

However, Mineral trioxide aggregate (MTA) is considered to be predictable, they present few limitations that are mainly related to its long setting time, difficult handling, and tooth discoloration for its use in endodontics.

A newly developed material based on pozzolan cement (Endocem, Maruchi, Seoul, Korea) has been manufactured in South Korea endorsing its short setting time (5 minutes). Even though the major component of a pozzolan cement is the amorphous or glassy silica, the Endocem is very similar to that of MTA in respect to chemical constituents 20% bismuth oxide (Bi_2O_3) is added for radiopacity and it is composed of 46.7% CaO, 5.43% Al_2O_3, 12.80% SiO_2, 3.03% MgO, 2.32% Fe_2O_3, 2.36% SO_3, 0.21% TiO_2, 14.5% H_2O/CO_2, and 11% Bi_2O_3 in wt.%. When mixed with sterile water, there is a gradual decrease in the amount of free calcium hydroxide and an increase in formation of calcium silicate hydrate ($CaO\ SiO_2\ nH_2O$), which lower the hydration heat, neutralize the pH and increase the compressive strength.[127]

According to the American Concrete Institute,[128] pozzolan is a siliceous or siliceous and aluminous material that possesses little or no cementitious value in itself; however, in a finely divided form and in the presence of water, it chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

MTA based cement was developed recently, which contains small particles of pozzolan cement without the addition of chemical accelerators, demonstrated a much shorter setting time than ProRoot MTA as well as antiwashout characteristics and a lack of surrounding marginal gaps.[129]

Root canal dentin should be adequately sealed with the biocompatible material to help maintain the integrity of the root filling-dentine interface to resist displacement under static conditions, during function and operative procedures.[130] This property can be evaluated *in vitro* in terms of bond strength, and the push-out test is a widely accepted method.[131]

In this study, open apex was created using the parallel post drill, Peeso reamer no.4 with the diameter of 1.3mm to create parallel root dentin wall to simulate the open apex and was standardized to all the samples. The present study utilized ultrasonic agitation with U-Files for the removal of intracanal medicaments from the root canal with the concern to abrade the canal walls of the dentin in teeth with open apex because the radicular dentin thickness would already been compromised.

Irrespective of the use of several techniques used with or without the aid of chelators, no method till now is proved to be effective in completely removing the intracanal medicament from the root canal walls. This rises concern regarding the effects of medicament residue on the adhesive strength of calcium silicate-based cements to root canal dentine, since it is crucial that these cements remain in place under dislodging forces such as condensation pressure of root filling materials or placement of posts or restorative materials.[132]

Proroot MTA has some shortcomings such as difficult handling properties, a prolonged setting time and potential discoloration of teeth or soft tissues.[133] To overcome these shortcomings new product have been developed in the market. Angelus MTA (Angelus, Londrina, Brazil) was developed as an alternative to ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK, USA). The chemical difference between them is that Angelus has calcium dihydrate as one of its components, which reduced its setting time and increased its workability.[134] Despite the decreased setting time, the main disadvantage of Angelus MTA resulting in tooth discoloration in coronal area which creates aesthetic problems.[135]

Endocem is an MTA-derived pozzalan cement (Maruchi, Wonjui-si, Korea) was introduced which contains fine particles of silica to accelerate the setting reaction.[136] This pozzolan-based cement material is a siliceous and aluminous material that reacts chemically with calcium hydroxide in the presence of water to form cementitious compounds, is known as the pozzolanic reaction.[137] Endocem lead to less discoloration and has short setting time compared with traditional MTA.[138]

ENDOCEM MTA is comparable to MTA in chemical composition with the aggregate of trioxide compounds, but handling properties and the ability to set quickly due to addition of small pozzolanic particles makes the difference in between them.[139]

In a laboratory study, it was suggested that hand condensation resulted in better adaptation and fewer voids than ultrasonic compaction.[140] In this study MTA was placed in the root canal using the conventional metal pluggers and the apical plug was created using the hand condensation technique. The MTA apical plug provides the barrier against which the root canal obturation can be done to prevent the microleakage from the root canal to the peri radicular tissue or vice versa. Therefore, the apical plug thickness is significant to prevent possible leakage. Many of the studies suggest appropriate thickness of the apical plug to be 3 mm to 5 mm. This study, standardized the apical plug thickness of 5mm which was condensed using hand pluggers. MTA without the gutta percha or sealers was used in order to eliminate any confounding factors.

The results of the present study, showed that Calcium hydroxide when used as an intracanal medicament improved the bond strength of MTA and Endocem MTA compared to the control group. The reason being the Calcium hydroxide convertsch to calcium carbonate or to the reaction of MTA with residual Calcium hydroxide.[141] Thus, in this study, the residual calcium hydroxide that remained in the dentinal tubules was found to increase the bond strength of calcium silicate cements by supplying residual calcium ions. The results were in accordance with similar studies conducted by Nagas et al. [79] stating that prior medication with Calcium hydroxide significantly improved the bond strength to root dentin. In addition, Felippe et al. [142] in his study concluded that Calcium hydroxide had a positive effect on the bond strength of a calcium silicate-based sealer to dentin.

The bond strength of MTA and Endocem MTA with the prior application of Ledermix paste showed the least bond strength compared to the control group. This may be due to the reason that Ledermix containing the demeclocycline and triamcinolone has less molecular weight resulting in greater diffusion into the dentinal tubules. It was also reported that tetracyclines form a relatively strong, reversible bond with the hard-dental tissues and that they exhibit a slow release over an extended period of time. [143] This result was similar to the study conducted by Nagas et al. [79] which stated that Triple Antibiotic Paste, Augmentin, Ledermix was associated with debonding force of MTA and Biodentine.

Also, in this study it was found that the bond strength of Endocem MTA was greater than MTA with the prior application of Calcium hydroxide. The Endocem MTA possess a very similar chemical composition to that of MTA, and small pozzolanic particles are added to their composition. These small particles are attributed to the pozzolanic reaction in which calcium hydroxide is consumed to produce calcium silicate hydrate and calcium aluminate hydrate products.[144] These products form the stable crystals within the dentinal tubules that enhance the strength of the cements.[137]

SUMMARY

The root-end filling materials should be biocompatible with the tissue fluids and closely adapt to the walls of root end preparation, be radio opaque and dimensionally stable. To obtain these functional characteristics the filling materials should adhere to the dentinal walls and provide a hermetic seal.

In regenerative endodontic procedure, the intracanal medicaments were placed as an inter-appointment dressing followed by obturation. The concern arises particularly when the involved tooth is immature and the apex closure is incomplete. Therefore, the instrumentation in these cases is kept minimal because the teeth with open apex already has a thin dentinal wall which is prone to fracture. The calcium hydroxide dressing placed as intracanal dressing should be removed completely for the restorative material to bind to the dentinal wall.

The removal of calcium hydroxide is done with the ultrasonic U-files in this study as this results in minimal tooth structure abrasion. The calcium silicate materials are used as root-end filling materials as they are biocompatible, and have the tendency to form the interface between the root filling materials and the contacted tissue surface. In our study, the push-out bond strength between the MTA Angelus and Endocem MTA was compared after the use of calcium hydroxide, Ledermix paste as intracanal medicaments. It is found that the Endocem MTA after the use of calcium hydroxide intracanal medicament showed better bond strength compared to MTA. However further in-vivo and long term follow up studies required to substantiate our study results.

CONCLUSION

Within the limitations of the study methodology and performed procedures, the bond strength of MTA and Endocem MTA are improved with the prior application of Calcium hydroxide as an intracanal medicament compared to the control group. Among the MTA and Endocem MTA, the Endocem MTA was found to have superior bond strength compared to MTA.

BIBLIOGRAPHY

1. Textbook of endodontics. *Cohen 6th edition. 552-563*.

2. KAKEHASHI S, STANLEY HR, FITZGERALD RJ. The effects of surgical exposure of dental pulps in germ-free and conventional laboratory rats. *Oral Surg Oral Med Oral Pathol 1965;8(3):340-8*.

3. SIQUEIRA JR JF. Strategies to treat infected root canals. *J Calif Dent Assoc 2001; 29(12):825-37.*

4. GARTNER AH, DORN S. Retrograde filling materials: Retrospective success-failure study of amalgam, EBA, IRM. *JOE 1990;16(8):391-393*.

5. GEETA ASTHANA et al Bioactive Materials: A Comprehensive Review. *Sch. J. App. Med.Sci.2014;2(6E):3231-3237.*

6. R VINODDHINE, S PRADEEP. A review on bioactive materials used in endodontics. *IJPT 2015; 7:2:3273-3281*.

7. CAMILLERI J, PITT FORD TR. Mineral trioxide aggregate: a review of the constituents and biological properties of the material. *International Endodontic Journal. 2006; 39(10):747-54.*

8. RAO A, RAO A, SHENOY R. Mineral trioxide aggregate—a review. *Journal of Clinical Pediatric Dentistry. 2009; 34(1):1-8.*

9. PARIROKH M, TORABINEJAD M. Mineral trioxide aggregate: a comprehensive literature review–Part I: chemical, physical, and antibacterial properties. *J Endod 2010; 36:16-27.*

10. CHOI Y, PARK SJ, LEE SH, HWANG YC, YU MK, MIN KS, Biological effects and washout resistance of a newly developed fast-setting pozzolan cement. J endod 2013; 39:467-472.

11. Oral Histology – *A.R.Ten Cate, Mosby Publications (3rd edition).*

12. Mechanism of tooth eruption – T.B. Kandos. *B.D.J. Vol.181, No. 3 Aug.10: 1996 (91-95).*

13. CHEN X, BAO Z, LIU Y, LUI M, JIN X, XU X. Regenerative endodontic treatment of an immature permanent tooth at an early stage of root development: a case report. *J Endod 2013; 39:719–22.*

14. BABITAAHLAWAT, ASHOK KUMAR, NAVDHA CHAUDHARY, VIJAYLAXMY, VINOD BHARDWAJ. Apexification with rapid MTA plug technique. *Indian J.Sci.Res. 6(2): 153-156, 2015.*

15. CEHRELI Z, SARA S, UYSAL S, TURGUT MD. MTA apical plugs in the treatment of traumatized immature teeth with large periapical lesions. *Dent Traumatol 2011; 27: 59–62.*

16. CAMP JH. Diagnosis dilemmas in vital pulp therapy: treatment for the toothache is changing, especially in young, immature teeth. *Pediatr Dent 2008; 30:197–205*.

17. DEVEAUX E, HILDELBERT P, NEUT C, BONIFACE B, ROMOND C. Bacterial microleakage of Cavit, IRM, and TERM. *Oral Surg Oral Med Oral Pathol 1992;74: 634-43.*

18. SJÖGREN U, FIGDOR D, SPÅNGBERG L, SUNDQVIST G. The antimicrobial effect of calcium hydroxide as a short-term intracanal dressing. *Int Endod J 1991; 24:119-25.*

19. SUNDQVIST G. Bacteriological studies of necrotic dental pulps [dissertation]. *Umeå, Sweden: Umeå University; 1976.*

20. SJÖGREN U. Success and failure in endodontics [dissertation]. *Umeå, Sweden: Umeå University; 1996.*

21. TROPE M, DELANO EO, ØRSTAVIK D. Endodontic treatment of teeth with apical periodontitis: single vs. multivisit treatment. *J Endod 1999; 25:345-50.*

22. HERMANN BW. Calcium hydroxyd als Mittel Zum Behandel und Fullen Von Zahnwurzelkana len. Wuzburg: *Med Diss, 1920*.

23. WEINER RS. Liners, bases, and cements: a solid foundation. *Gen Dent 2002; 50:442– 6.*

24. CVEK M. Treatment of non-vital permanent incisors with calcium hydroxide. II. Effect on external root resorption in luxated teeth compared with effect of root filling with guttapucha. A follow-up. *Odontol Revy 1973; 24:343–54*.

25. HEITHERSAY GS. Stimulation of root formation in incompletely developed pulpless teeth. *Oral Surg Oral Med Oral Pathol 1970; 29:620 –30.*

26. FOREMAN PC, BARNES IE. Review of calcium hydroxide. *Int Endod J 1990; 23:283–97.*

27. NERWICH A, FIGDOR D, MESSER HH. pH changes in root dentin over a 4-week period following root canal dressing with calcium hydroxide. *J Endod 1993; 19:302– 6.*

28. SHEEHY EC, ROBERTS GJ. Use of calcium hydroxide for apical barrier formation and healing in non-vital immature permanent teeth: a review. *Br Dent J 1997; 183:241– 6.*

29. CVEK M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. *Endod Dent Traumatol 1992; 8:45–55.*

30. COHEN M, GARNICK JJ, RINGLE RD, HANES PJ, THOMPSON WO. Calcium and phosphorus content of root exposed to the oral environment. *J Clin Periodontol 1992; 19:268e73.*

31. ANDREASEN JO, FARIK B,MUNKSGAARD EC. Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. *Dent Traumatol 2002; 18:134-137.*

32. BAUMGARTNER JC, XIA T (2003) Antibiotic susceptibility of bacteria associated with endodontic abscesses. *Journal of Endodontics 29, 44–7.*

33. EHRMANN EH, MESSER HH, ADAMS GG. The relationship of intracanal medicaments to postoperative pain in endodontics. *Int Endod J 2003; 36:868-75.*

34. ATHANASSIADIS B, ABBOTT PV, WALSH LJ. The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. *Aust Dent J 2007;52: S64-82.*

35. KAWASHIMA N, WADACHI R, SUDA H, YENG T, PARASHOS P (2009) Root canal medicaments. *International Dental Journal 59, 5-11*.

36. GLEN E. DOYON, THOM DUMSHA AND J. ANTHONY VON FRAUNHOFER. Fracture Resistance of Human Root Dentin Exposed to Intracanal Calcium Hydroxide. JOE — 2005; 31:895-97

37. ROSENBERG B, MURRAY PE, NAMEROW, K. The effect of calcium hydroxide root filling on dentin fracture strength. *Dental Traumatology 2007; 23: 26–29.*

38. R. PACE, V. GIULIANI, L. PINI PRATO, T. BACCETTI & G. PAGAVINO. Apical plug technique using mineral trioxide aggregate: results from a case series. *International Endodontic Journal*, *40, 478–484, 2007*.

39. SURESH NANDINI, NATANASABAPATHY VELMURUGAN, AND DEIVANAYAGAM KANDASWAMY. Removal Efficiency of Calcium Hydroxide Intracanal Medicament with Two Calcium Chelators: Volumetric Analysis Using Spiral CT, An In Vitro Study.

40. ZAHED MOHAMMED. Sealing Ability of MTA Cements as Orthograde Root Filling Materials. *Pesq Bras Odontoped Clin Integr, João Pessoa, 8(3):267-270*.

41. DAVID E. WITHERSPOON, JOEL C. SMALL, JOHN D. Regan and Martha Nunn. Retrospective Analysis of Open Apex Teeth Obturated with Mineral Trioxide Aggregate. *JOE — 2008; 31:1171-76.*

42. ARATHI RAO, ASHWINI RAO AND RAMYA SHENOY. Mineral Trioxide Aggregate—*A Review. J Clin Pediatr Dent 34(1): 1–8, 2009.*

43. DENISE PONTES RALDI, et al. Treatment Options for Teeth with Open Apices and Apical Periodontitis. *JCDA 2009;75(8):591-96.*

44. SAFOORA SAHEBI1, FARIBORZ , MOAZAMI1, PAUL ABBOTT. The effects of short-term calcium hydroxide application on the strength of dentine. *Dental Traumatology 2010; 26: 43–46.*

45. M. TORABINEJAD , M. PARIROKH & P. M. H. DUMMER. Mineral trioxide aggregate and other bioactive endodontic cements: an updated overview – part II: other clinical applications and complications. *International Endodontic Journal, 51, 284–317, 2018.*

46. TINA RO¨ DIG, MANJA HIRSCHLEB, ANTONIA ZAPF & MICHAEL HUSMANN. Comparison of ultrasonic irrigation and RinsEndo for the removal of calcium hydroxide and Ledermix paste from root canals. *International Endodontic Journal, 44, 1155–1161, 2011.*

47. EUN-JUNG SHIN et al. The effects of short-term application of calcium hydroxide on dentin fracture strength. *Kor Acad Cons Dent 2011;36(5):425-430.*

48. NAIANA VIANA VIOLA et al. MTA versus Portland cement: review of literature. *RSBO. 2011;8(4):446-52.*

49. RONALDO ARAÚJO SOUZA et al. Healing of a Tooth with an Over instrumented Apex, Extensive Transportation and Periapical Lesion Using a 5 mm Calcium Hydroxide Apical Plug: An 8-Year Follow-up Report. *Braz Dent J 2012 23(5): 608-611.*

50. BEENA.S, CHANDRASHEKAR. L. Traditional Method of Management of an Open Apex in Maxillary Central Incisor. *Journal of Dental Sciences and Research 2011; 2(2),1-5.*

51. M. GIOVARRUSCIO et al. A technique for placement of apical MTA plugs using modified Thermafil carriers for the filling of canals with wide apices. *International Endodontic Journal, 46, 88–97, 2013.*

52. MOHAMMED MUSTAFA, et al. Role of Calcium Hydroxide in Endodontics: A review. *GJMEDPH, 2012;1(1):66-70.*

53. TÂNIA AFONSO, et al. Effect of calcium hydroxide as intracanal medication on the apical sealing ability of mineral trioxide aggregate (MTA): an in vitro apexification model. *J Health Sci Inst. 2012;30(4):318-22.*

54. ALLEN N. SAWYER, et al. Effects of calcium silicate- based materials on the flexural strength of dentin. *JOE 2012;38(5):680-83*.

55. ANDERSON DE OLIVEIRA PAULO et al. Apexification with white MTA in an immature permanent tooth with dens invaginatus. *Braz J Oral Sci. 12(1):61-65.*

56. MURUGESAN GAWTHAMAN et al. Apexification with calcium hydroxide and mineral trioxide aggregate: Report of two cases. *J Pharm Bioall Sci 2013;5:131-4.*

57. G. H. YASSEN, M. VAIL, G. CHU & PLATT. The effect of medicaments used in endodontic regeneration on root fracture and microhardness of radicular dentine. *International Endodontic Journal, 46, 688–695, 2013.*

58. GA-YEON JANG et al. Washout resistance of fast-setting pozzolan cement under various root canal irrigants. *Restor Dent Endod 2013;38(4):248-252.*

59. JI-HYUN JANG et al. Tooth Discoloration after the Use of New Pozzolan Cement (Endocem) and Mineral Trioxide Aggregate and the Effects of Internal Bleaching. *J Endod 2013; 39:1598–1602.*

60. YOORINA CHOI et al. Biological Effects and Washout Resistance of a Newly Developed Fast-setting Pozzolan Cement. *J Endod 2013; 39:467–472.*

61. SEOK-WOO CHANG et al. Long-term observation of the mineral trioxide aggregate extrusion into the periapical lesion: a case series. *International Journal of Oral Science (2013) 5, 54–57.*

62. DIVYA. D et al. All Is Well That Ends Well. A Review on Root End Filling Materials. *Journal of Dental Sciences and Research 2014;5(2):12-15.*

63. NIRAV J. PARMAR et al. Root-end Filling Materials: Review Literature. *Heal Talk 2014; 6(3):32-34.*

64. SU-JUNG PARK et al. Odontogenic Effect of a Fast-setting Pozzolan-based Pulp Capping Material. *J Endod 2014;1–8.*

65. MIRI KIM et al. Comparison of the Biological Properties of ProRoot MTA, OrthoMTA, and Endocem MTA Cements. *J Endod 2014;1–5.*

66. MINJU SONG et al. Cytotoxicity of newly developed pozzolan cement and other root-end filling materials on human periodontal ligament cell. *Restor Dent Endod 2014;39(1):39-44.*

67. L. HAN, S. KODAMA & T. OKIJI. Evaluation of calcium-releasing and apatite-forming abilities of fast-setting calcium silicate-based endodontic materials. *International Endodontic Journal, 48, 124–130, 2015.*

68. MAURA CRISTIANE GONÇALES ORÇATI DORILEO et al. *International Scholarly Research Notices 2014; 1-7.*

69. MURVINDRAN.V, DR.JAMES.D.RAJ. Antibiotics as an Intracanal Medicament in Endodontics. *J. Pharm. Sci. & Res. Vol. 6(9), 2014, 297-301.*

70. M. KUNDABALA, S. JAGADISH, S. RAMYA. Efficacy of Ledermix as a root canal medicament in symptomatic teeth: A clinical study. *Journal of Interdisciplinary Dentistry 2014; 4(2):85-88.*

71. REVATHI. N1, SHARATH CHANDRA S. Merits and Demerits of Calcium Hydroxide as a Therapeutic Agent: A Review. *International Journal of Dental Sciences and Research, 2014; 2(6B):1-4.*

72. SANJANA A PATIL, AVINASH A PATIL, PREETI K DODWAD. Management of Non-Vital Teeth with Open Apices using MTA as an Apical Plug: Two Case Reports. *World Journal of Dentistry, January-March 2011;2(1):45-48.*

73. A. C. BHUYAN, MUKUT SEAL, KARTIK PENDHARKAR. Effectiveness of four different techniques in removing intracanal medicament from the root canals: An in vitro study. *Contemp Clin Dent 2015; 6:309-12.*

74. NIKHIL VINEETA, SACHIN GUPTA, ADITI CHANDRA et al. Retrievabilty of calcium hydroxide intracanal medicament with Chitosan from root canals: An in vitro CBCT volumetric analysis. *J Conserv Dent 2014; 17:454-7.*

75. SEHNAZ YILMAZ, AYSIN DUMANI, OGUZ YOLDAS. The effect of antibiotic pastes on microhardness of dentin. *Dental Traumatology 2016; 32: 27–31.*

76. GHAETH HAMDON YASSEN et al. Effect of intracanal medicaments used in endodontic regeneration procedures on microhardness and chemical structure of dentin. *Restor Dent Endod 2015;40(2):104-112.*

77. TUGBA TURK & ALEŠ FIDLER. Effect of medicaments used in endodontic regeneration technique on push-out bond strength of MTA and Biodentine. *Biotechnology & Biotechnological Equipment, 2015.*

78. A.A. ELGENDY, M.M. NAGY. The effect of different intracanal medications on fracture resistance of root canal dentin. *Tanta Dental Journal 12 (2015) 163-167.*

79. E.NAGAS et al. Effect of several intracanal medicaments on the push-out bond strength of ProRoot MTA and Biodentine.

80. BABITAAHLAWAT et al. Apexification with rapid MTA plug technique. *Indian J.Sci.Res. 6(2): 153-156, 2015.*

81. ALEJANDRA CITLALLI RODRÍGUEZ ROCHA et al. Physicochemical analysis of MTA Angelus® and Biodentine® conducted with X ray difraction, dispersive energy spectrometry, X ray Fluorescence, scanning electron microscope and infra red spectroscopy. *Revista Odontológica Mexicana 2015;19 (3): e170-e176.*

82. PETER Z TAWIL et al. MTA: A Clinical Review. *Compend Contin Educ Dent. 2015 April; 36(4): 247–264.*

83. ABHIJEET KAMALKISHOR KAKANI et al. Mineral Trioxide Aggregate as an Apical Plug Material in Tooth with Open Apex: A Case Report. *International Journal of Scientific Study 2015; 2(11): 218-221.*

84. RAIDAN BA-HATTAB et al. Calcium Hydroxide in Endodontics: An Overview. *Open Journal of Stomatology, 2016, 6, 274-289.*

85. B.S. KESHAVA PRASAD and DR. CHITRA T. NAIK. Mineral trioxide aggregate in endodontics. *IJADS 2016; 3(1): 71-75.*

86. EMMANUEL JOAO NOGUERIRA LEAL SILVA et al. Puah-out Bond strength of Fast-setting Mineral Trioxide Aggregate and Pozzolan-based Cements: ENDOCEM MTA and ENDOCEM Zr. *JOE 2016; 4:1-4.*

87. ERSAN CICEK et al. Effect of Mineral Trioxide Aggregate Apical Plug Thickness on Fracture Resistance of Immature Teeth. *J Endod 2017:1–4.*

88. NEGIN GHASEMI et al. Effect of different mixing and placement methods on the quality of MTA apical plug in simulated apexification model. *J Clin Exp Dent. 2017;9(3):e351-5.*

89. AGRAFIOTI et al. Analysis of clinical studies related to apexification techniques. *European Journal of Paediatric Dentistry vol. 18/4-2017 273-284.*

90. MOHAMMADREZA NABAVIZADEH et al. The Effect of Intracanal Medicaments on Microleakage of Mineral Trioxide Aggregate Apical Plugs. *Iranian Endodontic Journal 2017;12(3): 329-333.*

91. MERVE NUR AYDIN & BURAK BULDUR. The effect of intracanal placement of various medicaments on the bond strength of three calcium silicate-based cements to root canal dentin. *Journal of Adhesion Science and Technology 2017: 1-17.*

92. CH JONKER and PJ VAN DER VYVER. Apexification of immature teeth using an apical matrix and MTA barrier material: Report of two cases. *SADJ October 2017, 72(9) 414 - 419.*

93. KANCHAN BHAGAT et al. Root end filling materials and recent advances: A review. *Dental Science 2017; 7(6):257-260.*

94. MANDEEP KAUR et al. MTA versus Biodentine: Review of Literature with a Comparative Analysis. *Journal of Clinical and Diagnostic Research. 2017;11(8): 01-05.*

95. IVAN MATOVIĆ et al. The application of MTA as apical plug for root canal obturation – in vitro study. *Serbian Dental Journal 2018; 65(2):71-77.*

96. PRADNYA V et al. Pozzolan Dental Cement: A review. *IOSR Journal of Dental and Medical Sciences 2018; 17(4): 07-09.*

97. ELIF AYBALA OKTAY et al. Effect of intracanal medicaments used in endodontic regeneration on the push-out bond strength of a calciumphosphate-silicate-based cement to dentin. *Pak J Med Sci. 2018;34(2):310-315.*

98. SUZAN ABDUL WANEES AMIN and SHAIMAA ISMAIL GAWDAT. Retention of BioAggregate and MTA as coronal plugs after intracanal medication for regenerative endodontic procedures: an ex vivo study. *Restor Dent Endod. 2018 Aug;43(3):e18.*

99. MADHUMITHA JAYAKUMAR et al. MTA: A review of literature with clinical applications. *Journal of Dental and Medical Sciences 2018; 17(3): 04-11.*

100. KADRIYE DEMIRKAYA et al. Evaluation of micro surface structure and chemical composition of two different calcium silicate–containing filling materials. *Turk Endod J 2018;3(1):10–14*.

101. LUIZ ALEXANDRE CHISINI et al. Revascularization versus apical barrier technique with mineral trioxide aggregate plug: A systematic review. *Giornale Italiano di Endodonzia 2018: 01-08.*

102. Anonymous. Glossary of endodontic terms. 7th ed. Chicago: *American Association of Endodontists, 2003.*

103. GRANATH LE. Some notes on the treatment of traumatized incisors in children. *Odont Rev 1959;10:272.*

104. CHAWLA HS. Apexification: follow-up after 6 –12 years. *J Indian Soc Pedod Prev Dent 1991;8:38–40.*

105. FRANK AL. Therapy for the divergent pulpless tooth by continued apical formation. *J Am Dent Assoc 1966;72:87–93.*

106. MOHAMMADI Z. Strategies to manage permanent nonvital teeth with open apices: a clinical update. *Int Dent J 2011; 61: 25–30.*

107. ANDREASEN JO. Treatment of fractured and avulsed teeth. *ASDC J Dent Child 1971;38:29–31.*

108. WITHERSPOON DE, SMALL JC, REGAN JD, NUNN M. Retrospective analysis of open apex teeth obturated with mineral trioxide aggregate. *J Endod 2008; 34:1171-6.*

109. WITHERSPOON DE, HAM K. One-visit apexification: technique for inducing root-end barrier formation in apical closures. *Pract Proced Aesthet Dent. 2001(6);13:455-60.*

110. PARIROKH M, TORABINEJAD M. Mineral trioxide aggregate: A comprehensive literature review. Part III: Clinical applications, drawbacks, and mechanism of action. *J Endod. 2010;36(3):400-13.*

111. LAW A, MESSER H. An evidence-based analysis of the antibacterial effectiveness of intracanal medicaments. *J Endod. 2004; 30(10): 689-94.*

112. PARIROKH M, TORABINEJAD M. Mineral trioxide aggregate: a comprehensive literature review. Part I: chemical, physical, and antibacterial properties. *J Endod. 2010;36(1):16-27.*

113. KIM SK, KIM YO. Influence of calcium hydroxide intracanal medication on apical seal. *Int Endod J. 2002;35(7):623-8.*

114. BALVEDI RPA, VERSIANI MA, MANNA FF, BIFFI JCG. A comparison of two techniques for the removal of calcium hydroxide from root canals. *Int Endod J. 2010;43(9):763-8.*

115. YOSHIBA K, YOSHIBA N, IWAKU M. Histological observations of hard tissue barrier formation in amputated dental pulp capped with alpha-tricalcium phosphate containing calcium hydroxide. *Endod Dent Traumatol 1994;10:113–20.*

116. ZMENER O, PAMEIJER CH, BANEGAS G. An in vitro study of the pH of three calcium hydroxide dressing materials. *Dent Traumatol 2007;23:21–5.*

117. HOLLAND R, DE SOUZA V. Ability of a new calcium hydroxide root canal filling material to induce hard tissue formation. *J Endod 1985;11:535–43.*

118. BRANNSTROM M, VOJINOVIC O, NORDENVALL KJ. Bacteria and pulpal reactions under silicate cement restorations. *J Prosthet Dent 1979;41:290–5.*

119. FISHER FJ, MCCABE JF. Calcium hydroxide base materials. An investigation into the relationship between chemical structure and antibacterial properties. *Br Dent J 1978;144:341–4.*

120. ANDREASEN FM, ANDREASEN JO, BAYER T. Prognosis of rootfractured permanent incisors – prediction of healing modalities. *Endod Dent Traumatol 1989;5:11–22.*

121. ABBOTT PV. Medicaments: aids to success in endodontics. Part 1. A review of the literature. *Aust Dent J. 1990; 35(5):438-48.*

122. MURVINDRAN. V et al. Antibiotics as an Intracanal Medicament in Endodontics. *J. Pharm. Sci. & Res. Vol. 6(9), 2014, 297-301.*

123. TORABINEJAD M, HONG CU, MCDONALD F, PITT FORD TR. Physical and chemical properties of a new root-end filling materials. *J Endod, 21:349–53, 1995.*

124. DAMMASCHKE T, GERTH HUV, ZUCHNER H, SCHAFER E. Chemical and physical surface and bulk material characterization of white ProRoot MTA and two Portland cements. *Dent Mater, 21: 731–738, 2005.*

125. SONG J, MANTE FK, ROMANOWWJ, KIM S. Chemical analysis of powder and set forms of Portland cement, gray ProRoot MTA, Shite ProRoot MTA and Gray MTA-Angelus. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 102: 809–815, 2006.*

126. ASGARY S, PARIROKH M, EGBBAL MJ, BRINK F. Chemical differences between white and gray mineral trioxide aggregate. *J Endod, 31:101–103, 2005.*

127. SONG M et al. Cytotoxicity of newly developed pozzolan cement and other root-end filling materials on human periodontal ligament cell. *J of Restorative Dentistry and Endodontics. 39-44,2013.*

128. American Concrete Institute, Cement and Concrete Terminology, *ACI 116R, ACI, Farmington Hills, Mich, USA, 1985.*

129. Y. CHOI, S.-J. PARK, S.-H. LEE, Y.-C. HWANG, M.-K. YU, AND K.-S. MIN, “Biological effects and washout resistance of a newly developed fast-setting pozzolan cement,” *Journal of Endodontics, vol. 39, no. 4, pp. 467–472, 2013.*

130. TAGGER M, TAGGER E, TJAN AHL, BAKLAND LK (2002) Measurement of adhesion of endodontic sealers to dentin. *Journal of Endodontics 28, 351-4.*

131. PANITVISAI P, MESSER HH (1995) Cuspal deflection in molars in relation to endodontic and restorative procedures. *Journal of Endodontics 21, 57-61.*

132. TORABINEJAD M, HIGA RK, MCKENDRY DJ, PITT FORD TR (1994) Dye leakage of four root end filling materials: effects of blood contamination. *Journal of Endodontics 20, 159–63*

133. CHANG, S. W., BAE, W. J., YI, J. K., LEE, S., LEE, D. W., KUM, K. Y., & KIM, E. C. (2015). Odontoblastic differentiation, ınflammatory response, and angiogenic potential of 4 calcium silicate-based cements: Micromega MTA, ProRoot MTA, RetroMTA, and experimental calcium silicate cement. *Journal of Endodontics, 41(9), 1524–1529.*

134. DAMAS, B. A., WHEATER, M. A., BRINGAS, J. S., & HOEN, M. M. (2011). Cytotoxicity comparison of mineral trioxide aggregates and EndoSequence bioceramic root repair materials. *Journal of Endodontics, 37(3), 372–375.*

135. KESKIN, C., DEMIRYUREK, E. O., & OZYUREK, T. (2015). Color stabilities of calcium silicate–based materials in contact with different irrigation solutions. *Journal of Endodontics, 41(3), 409–411.*

136. PARK, S. J., HEO, S. M., HONG, S. O., HWANG, Y. C., LEE, K. W., & MIN, K. S. (2014). Odontogenic effect of a fast-setting pozzolan-based pulp capping material. *Journal of Endodontics, 40(8), 1124–1131.*

137. ASKARINEJAD, A., POURKHORSHIDI, A. R., & PARHIZKAR, T. (2012). Evaluation the pozzolanic reactivity of sonochemically fabricated nano natural pozzolan. *Ultrasonics Sonochemistry, 19(1), 119–124.*

138. JANG, J.-H., KANG, M., AHN, S., KIM, S., KIM, W., KIM, Y., & KIM, E. (2013). Tooth discoloration after the use of new pozzolan cement (Endocem) and mineral trioxide aggregate and the effects of internal bleaching. *Journal of Endodontics, 39(12), 1598–1602.*

139. KIM RJ, KIM MO, LEE KS, et al. An in vitro evaluation of the antibacterial properties of three mineral trioxide aggregate (MTA) against five oral bacteria. *Arch Oral Biol 2015;60:1497–502.*

140. AMINOSHARIAE A, HARTWELL GR, MOON PC (2003) Placement of mineral trioxide aggregate using two different techniques. *Journal of Endodontics 29, 679–82.*

141. BIDAR M, DISFANI R, GHARAGOZLOO S, et al. Medication with calcium hydroxide improved marginal adaptation of mineral trioxide aggregate apical barrier. *J Endod. 2010;36:1679-1682.*

142. FELIPPE WT, FELIPPE MC, ROCHA MJ (2006) The effect of mineral trioxide aggregate on the apexification and periapical healing of teeth with incomplete root formation. *International Endodontic Journal* **39**, 2-9.

143. BjORVATN K, SKAUG N, SELVIG KA. Tetracycline-impregnated enamel and dentin: duration of antimicrobial capacity. Scand J Dent Res 1985; 93: 192-7.

144. THEODORE C, SCRIVENER K. Alkali fixation of C-S-H in blended cement pastes and its relation to alkali silica reaction. *Cem Concr Res 2012;42:1049-54*.

No: VDCW/IEC/75/2017

Date: 30.12.2017

TO WHOMSOEVER IT MAY CONCERN

Principal Investigator: Dr. BRINDHA.L

Title: Comparative evaluation of effect of various intracanal medicaments on the push-out bond strength of MTA and Endocem MTA –An intro study

Institutional ethics committee thank you for your submission for approval of above proposal. It has been taken for discussion in the meeting held on 22.12.2017. The committee approves the project and it has no objection on the study being carried out in Vivekanandha Dental College for Women.

You are requested to submit the final report on completion of project. Any case of adverse reaction should be informed to the institutional ethics committee and action will be taken thereafter.

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