EFFICACY OF DIFFERENT IRRIGATION SYSTEMS ON REMOVAL OF CALCIUM HYDROXIDE FROM A SIMULATED INTERNAL RESORPTION CAVITY -AN IN-VITRO STUDY

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LIST OF ABBREVIATIONS

Sr. No	Abbreviations	Full form
01	BMP	Biomechanical Preparation
02	$Ca(OH)_2$	Calcium Hydroxide
03	CDC	Center for Disease Control
04	CH	Calcium Hydroxide
05	CMCP	Camphorated paramonochlorophenol
06	CSI	Conventional syringe irrigation
07	EA	Endoactivator
08	EDTA	Ethylene Diamine Tetra-acetic acid
09	GG	Gates Glidden
10	GP	Gutta Percha
11	HS	Highly Significant
12	i.e.	That is
13	IR	Internal Resorption
14	LPS	Lipopolysaccharide
15	MAF	Master Apical File
16	µCT	Micro Computed Tomography
17	mm	Millimeter
18	n.	Number of specimens in each group.
19	N	Total number of samples

20	NaOCl	Sodium Hypochlorite
21	Ni Ti	Nickel Titanium
22	no	Number
23	OSHA	Occupational Safety and Health Administration
24	OSM	Optical Stereomicroscope
25	P value	Probability of happening of an event
26	PAS	Periodic acid-Schiff
27	%	Percentage
28	PUI	Passive Ultrasonic Irrigation
29	RVG	Radiovisiography
30	SAF	Self-Adjusting file
31	SD	Standard Deviation
32	SEM	Scanning Electron Microscope
33	WL	Working Length
34	ZnOE	Zinc Oxide Eugenol

INTRODUCTION

INTRODUCTION

"An ounce of prevention is worth a pound of cure"

Benjamin Franklin

Clinical endodontics encompasses a number of treatments all with the common goal of preventing and eliminating microbial contamination of pulp and root canal system. Shaping and cleaning procedures as part of root canal treatment are directed towards microbial challenges of root canal system.[1] Planktonic microorganisms in the pulp cavity and coronal root canal may be readily killed by irrigants early in a procedure but bacteria in less accessible canal areas or biofilms can still elicit or maintain apical periodontitis.[2] The limitations of conventional chemomechanical debridement require the use of intracanal antimicrobial medications.[3]

According to the Glossary of the American Association of Endodontists, resorption is defined as a condition associated with either a physiologic or a pathologic process resulting in the loss of dentin, cementum, or bone.[4] It can occur both internally and externally and is known to be initiated and maintained by many factors; however pulpal necrosis, trauma, periodontal treatment, orthodontic treatment and tooth whitening agents are the most commonly described stimulants.[5] Irrespective of the initial cause, the process is largely inflammatory in origin. Root resorption in the permanent dentition is a pathologic event; if untreated, this might result in the premature loss of the affected teeth.[6]

Internal root resorption is described as a resorptive defect in the internal aspect of the root due to necrosis of odontoblasts occurring as a result of chronic inflammation and bacterial invasion of the pulp tissue.[7] The continuous bacterial stimulation causes chronic inflammation of the coronal pulp leading to transformation of normal pulp to granulomatous tissue with giant cells which resorb dentin. Trauma, caries and restorative procedures have been suggested to be contributing factors, but it also occurs as an idiopathic dystrophic change. Clinically, internal root resorption is usually asymptomatic and is detected coincidentally through routine radiographs.[8]

The treatment of internal resorption is a two-fold procedure. The first and most important aspect is an accurate diagnosis. Subsequently the second and most critical procedure is to remove the causative factors for the resorptive process: the bacteria and the necrotic pulpal tissue. This is achieved with shaping, cleaning and obturation of the root canal system. As a means of preventing continued resorption of the root, researchers have suggested leaving the medicament in place for several weeks.[9]

Calcium hydroxide [$Ca(OH)_2$] is the most widely used intracanal dressing material in endodontics due to its antibacterial and biological properties.[10] The clinical success of this material is attributed to its alkaline pH and depends on its ability to rapidly dissociate into hydroxyl and calcium ions.[11] $Ca(OH)_2$ has been used in various clinical situations and is left inside the canal for different time periods ranging from 7 days for intracanal medication to 6-24 months for apexification.[12]

$Ca(OH)_2$ placed inside the root canal has to be completely removed before obturating the canal with permanent obturating materials. Otherwise, remnants of $Ca(OH)_2$ can potentially interact with zinc oxide eugenol sealers, rendering them brittle and granular.[13] It also reduces the bond strength of resin-based sealer to root canal dentine (Barbizam et al. 2008)[14] and interferes with the sealing ability of silicon-based sealer (Contardo et al. 2007)[15]. Also calcium hydroxide when used as an intracanal medicament showed increased apical leakage when zinc oxide–eugenol sealer was used for obturation (Kim & Kim 2002)[13]. This can be explained by an accelerated setting of the sealer (Margelos et al. 1997)[16]. Remnants of calcium hydroxide on root canal surface causes decreased penetration of sealers into the dentinal tubules which results in potential reduction of sealer adaptation (Calt & Serper 1999)[17].

The removal of $Ca(OH)_2$ using a range of products and techniques has been investigated. The most frequently described method is instrumentation of the root canal using a master apical file and copious irrigation.[18] Nevertheless, canal irregularities and resorption cavities may be inaccessible using conventional procedures, which can leave the remnants of $Ca(OH)_2$ in root canal system. Therefore, different irrigation activation techniques have been proposed to improve the efficacy of irrigation solutions within the root canal system.

Calt & Serper (1999)[17] demonstrated complete removal of calcium hydroxide from the root canal after irrigation with EDTA followed by NaOCl in comparison to NaOCl alone. The flushing action of irrigants helps to remove the organic components, dentinal debris and microorganisms from the canal. This flushing action is found to be more important than the ability to dissolve tissues (Baker et al. 1975)[19]. Conventional irrigation with a syringe and needle still remains the widely accepted method. However, it has been demonstrated that the flushing action created by syringe irrigation is relatively weak (Abou-Rass & Piccinino 1982).[20]

Manual Dynamic Agitation has been described as a cost-effective technique for cleaning the walls of root canal system. It involves repeated insertion of a well-fitting gutta-percha cone to the working length of a previously shaped canal. The gutta-percha cone is used in short, gentle strokes of 100/min to produce an effective hydrodynamic effect and activation of the irrigant. When studied, Manual-Dynamic irrigation was found to be significantly more effective than RinsEndo irrigation system and static irrigation (Mc Gill et al 2008).[21]

The Canal Brush (CB) (Roeko Canal Brush TM Coltene/Whaledent, Langenau, Germany) is an endodontic microbrush. This highly flexible microbrush is moulded entirely from polypropylene and can be used manually with a rotary action.[22]

However, the brush was more efficient when operated at 600rpm in a contra-angle handpiece (Junqi Ling et al 2009).[23] It was reported that debris was effectively removed from simulated canal extensions and irregularities with the use of the small and flexible Canal Brush with an irrigant (Weise et al 2007).[24]

The EndoVac is a newer unique irrigation device that works on the principle of apical negative pressure. It draws irrigants apically through suction from the high-volume evacuation of the dental unit and safely delivers them to the apical terminus of root canals. The recommended protocol consists of two main phases: Macro and micro irrigation. This system has macro- and microcannula components that make the irrigating solution circulate due to difference of pressure caused by the vacuum inside the root canal system. The negative pressure overcomes the shortcomings encountered with positive pressure.[25]

No earlier studies have been performed comparing the efficacy of Manual Dynamic Agitation in removing calcium hydroxide from internal resorption cavity. It is a technique which can be easily employed by any dentist in daily procedures.

The null hypothesis evaluated in this study was that there is no difference in the efficacy of different irrigation techniques mentioned here in the removal of calcium hydroxide from internal resorption cavities of the root canal system.

AIM AND OBJECTIVES

AIM & OBJECTIVES

AIM:

To compare the efficacy of various irrigation techniques in removing calcium hydroxide from an experimental internal resorption cavity.

OBJECTIVES:

1. To evaluate the efficacy of conventional syringe irrigation technique in removing calcium hydroxide from the internal resorption cavity.

2. To evaluate the efficacy of irrigation with Manual Dynamic Agitation in removing calcium hydroxide from the internal resorption cavity.

3. To evaluate the efficacy of irrigation with Canal Brush in removing calcium hydroxide from the internal resorption cavity.

4. To evaluate the efficacy of EndoVac in removing calcium hydroxide from the internal resorption cavity.

5. To compare the efficacy of above mentioned systems in removal of calcium hydroxide from internal resorption cavity and to suggest the best technique for the same.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Calcium hydroxide is the most common intracanal medicament used nowadays. It is used for treating internal resorption. A number of methods have been employed till now for the removal of calcium hydroxide from the canal. Search for methods which are both economical and effective in removing calcium hydroxide has led to the introduction of newer irrigation techniques. Pearl S Buck truly stated that "If you want to understand today, you have to search yesterday". Thus before proceeding further, it is important to review internal resorption, role of calcium hydroxide and methods employed till now.

Bell **(1829)** first reported internal resorption. The tooth was extracted because of pain. The sectioned tooth showed a cavity in the dentine, despite normal surrounding bony tissues. He believed that this was caused by inflammation and that it contained the resultant pus.[26]

Miller **(1890)** described a tooth with an irregular cavity in the dentine resulting from suppuration of the pulp, absorption, or a combination of both of these.[27]

Gaskill **(1894)** presented a case of internal root resorption of a central incisor with no external opening.[28]

Mummery **(1920)** discussed the *"pink spots"* in teeth, but mentioned that such internal granulomata were of rare occurrence.[29]

Hermann B W **(1920)** first introduced calcium hydroxide (Calxyl) in endodontics as direct pulp capping agent.[30]

Euler **(1929)** presented a study in which he showed that granulation tissue may enter through the apical foramen and cause resorptive processes in the pulp canal.[31]

Hopewell-Smith **(1930)** stated that the causative agent for internal resorption are wandering cells. Upon irritation of the pulp, the wandering cells are carried into the pulp by the blood stream or by such agents in the periodontal membrane which might begin to resorb calcified tissue.[32]

Burstone **(1953)** showed in histochemical study that the glycoprotein ground substance of dentine in internal resorption is characterized by areas which exhibit a greater-than-normal periodic acid-Schiff (PAS) staining reaction. With the PAS staining method, internal resorption specimens were characterized by a red-staining zone adjacent to the area of resorption. One specimen of a partial necrosis of the pulp was characterized by an intense PAS-positive zone adjacent to the pulp. This striking change in the ground substance was thought to be a possible result of proteolytic activity by bacteria, superimposed upon the primary resorptive process.[33]

Heithersay **(1975)** reported that calcium hydroxide may act as a local buffer against the acidic reactions produced by the inflammatory process. An alkaline pH of 12.2 provided by calcium hydroxide may also neutralize the lactic acid secreted by osteoclasts, and this may help to prevent further destruction of mineralized tissue.[34]

Metzler & Montgomery **(1989)** reported that the ability of calcium hydroxide to dissolve necrotic tissue is useful, as anatomical problems often make it difficult for irrigating solutions to reach all areas of the root canal. In this respect, it has been found that when a calcium hydroxide dressing was used in addition to irrigation with sodium hypochlorite, the canal was cleaned as effectively as when ultrasonic instrumentation was used.[35]

Porkaew P, Retief DH, Barfield RD, Lacefield WR, Soong SJ **(1990)** evaluated the effect of calcium hydroxide paste as an intracanal medicament on apical seal. Seventy-six extracted human permanent canines and premolars with single canals were used in this study. The crowns were removed, the canals were instrumented, and the roots were randomly divided into four groups of 18 each. Three groups were medicated with $Ca(OH)_2$ USP, Calasept, and Vitapex, respectively, while the control group was not medicated. The roots were incubated in 100% relative humidity at 37̊C for 1 wk, after which the medicaments were removed and the canals were enlarged to the next file size. The teeth were obturated with guttapercha and then evaluated for both linear and volumetric dye penetration using 2% methylene blue.

The mean apical leakage values of the treated groups as determined by both linear and volumetric measurements were significantly lower than the mean apical leakage value of the control group (no medication).[36]

Sjogren U, Figdor D, Spangberg L, Sundqvist G **(1991)** evaluated the antimicrobial effect of calcium hydroxide. Calcium hydroxide was used as a short term dressing. Clinical evaluation was done by applying the medicament for 10 minutes or 7 days in root canals of teeth with periapical lesions. Antimicrobial effects of calcium hydroxide were shown to be best achieved if the canals were dressed with calcium hydroxide for at least 7 days.[37]

Estrela C, Sydney GB, Bammann LL, Felippe Junior O **(1995)** reported that hydroxyl component is the most important component of calcium hydroxide. It encourages repair and active calcification. Alkaline pH neutralizes lactic acid formed from osteoclasts, preventing dissolution of mineral components of dentin and activates alkaline phosphatase that plays role in hard tissue formation.[38]

Margelos J, Eliades G, Verdelis C, Palaghias G **(1997)** evaluated the interaction of calcium hydroxide with zinc oxide-eugenol type sealers. When a ZnOE type sealer was placed in root canals treated previously with calcium hydroxide dressing, an accelerated sealer setting rate was seen. The set ZnOE cement and the ZnOE type sealers in contact with calcium hydroxide were brittle in consistency and granular in structure. The main problems they reported was a gradual reduction in sealer viscosity and resistance in the delivery of gutta-percha cones that failed to reach full working length.[16]

Sjogren U, Figdor D, Persson S, Sundqvist G **(1997)** concluded that the use of NaOCl in concentration of 0.5-5% has intracanal antimicrobial activity but still 40-60% canals have detectable cultivable bacteria. Residual bacteria can adversely affect treatment outcome. The use of inter-appointment intracanal medication has been recommended to supplement the antibacterial effects of chemo-mechanical procedure and maximize bacterial reduction.[39]

Calt S, Serper A **(1999)** evaluated the dentinal tubule penetration of root canal sealers after root canal dressing with calcium hydroxide. Forty-two single-rooted teeth were instrumented to size 60. Six teeth served as the control group and the remaining teeth were assigned to two groups. Root canals of the first group were filled with the $Ca(OH)_2$ paste; the second group was filled with TempCanal, and all were incubated for 7 days. The samples were either irrigated with only NaOCI or with EDTA, followed by NaOCI to remove $Ca(OH)_2$. All of the teeth were obturated with CRCS, AH26, and KetacEndo by a lateral condensation technique. The specimens were then evaluated under scanning electron microscope. It was reported that $Ca(OH)_2$ was not completely removed from the root canal surfaces, and root canal sealers did not penetrate into the dentinal tubules when only NaOCI was used. EDTA followed by NaOCI irrigation resulted in complete removal of $Ca(OH)_2$ and root canal sealers penetrated into the dentinal tubules.[17]

Siquera J F **(2001)** demonstrated the mechanism of antimicrobial activity of calcium hydroxide. They found antimicrobial activity to be dependent on release of hydroxyl ions in the aqueous environment. The lethal effects of hydroxyl ions on bacterial cells are due to damage to bacterial cytoplasmic membrane, denaturation of protein or damage to DNA.[40]

Jiang J, Zuo J, Chen SH, Holliday LS **(2003)** evaluated the effect of calcium hydroxide on LPS stimulated osteoclast formation. LPS has direct stimulatory effect on later stages of RANKL-initiated osteoclast formation. Detoxification of LPS with calcium hydroxide inhibited osteoclast formation. This might be one of the mechanisms by which interappointment $Ca(OH)_2$ dressings create a favorable environment for periapical bone healing.[41]

Vier FV, Figueiredo JA **(2004)** evaluated by SEM the presence and extent of internal resorption in the apical third in a sample of roots of human teeth with periapical lesions. Apical internal resorption was found in 74.7% of roots associated with periapical lesions.[42]

Nandini S, Velmurugan N, Kandaswamy D **(2006)** reported that vehicle used to prepare calcium hydroxide was important for removal. In this study, access cavities were prepared in 40 single rooted anterior teeth. After cleaning and shaping canals were filled with either Metapex or pure calcium hydroxide powder in distilled water. After 7 days the calcium hydroxide was retrieved using either 17% EDTA or 10% citric acid in combination with ultrasonic agitation. Volume analysis was done using spiral computed tomography. The 17% EDTA showed excellent removal efficiency of powder form of calcium hydroxide in distilled water than Metapex ($p < 0.001$). Ten percent citric acid removed powder form of calcium hydroxide in distilled water better than Metapex ($p = 0.05$). Oil based calcium hydroxide was difficult to remove than calcium hydroxide mixed with distilled water.[43]

Nielsen BA, Craig Baumgartner J **(2007)** compared the efficacy of the EndoVac irrigation system and needle irrigation to debride root canals at 1 and 3 mm from working length. One tooth of each matched pair was instrumented and irrigated by using the EndoVac, which uses negative pressure to deliver irrigating solutions to working length. The other tooth of the matched pair was instrumented and irrigated with a 30-gauge ProRinse irrigating needle. All teeth were irrigated with sodium hypochlorite (NaOCl) and ethylenediamine tetraacetic acid (EDTA) for a predetermined amount of time, and total volume of irrigant used was recorded. After instrumentation and irrigation, the teeth were fixed, decalcified, and sectioned at 1 mm and 3 mm from working length. Serial sections were made and digitally photographed. The amount of remaining debris was determined as a percentage of the area of the canal lumen. At the 1-mm level, significantly less debris was found in the EndoVac group ($p < 0.0347$). At the 3-mm level, there was no significant difference between groups. This study showed significantly better debridement at 1 mm from working length by using the EndoVac compared with needle irrigation.[44]

Joao Vicente Baroni Barbizam, Martin Trope, Erica C.N. Teixeira, Mario Tanomaru-Filho, Fabricio B. Teixeira **(2008)** evaluated bond strength of epiphany resin based sealer to dentin walls after placement of calcium hydroxide as an intracanal medicament. It was concluded that use of calcium hydroxide as an intracanal dressing material affected adhesion of epiphany to root canal walls but the values were within acceptable range.[45]

Balvedi RP, Versiani MA, Manna FF, Biffi JC **(2010)** compared the ability of two irrigant regimens to remove calcium hydroxide (CH) mixed with different vehicles from root canal walls. The root canals of 92 freshly extracted bovine incisor teeth were prepared with a step-back technique and randomly assigned into two experimental groups (n = 40), whilst the remaining teeth (n = 12) served as positive and negative controls. In each experimental group, ten teeth were assigned to each calcium hydroxide preparation: G1 – Calcium hydroxide powder; G2 – Calcium hydroxide + saline solution; G3 – Calcium hydroxide + polyethylene glycol; G4 – Calcium hydroxide + polyethylene glycol + camphorated paramonochlorophenol (CPMC). The negative control did not receive calcium hydroxide placement, and the positive control received the intracanal dressing, but no subsequent removal. After 7 days, the CH was retrieved using manual or passive ultrasonic irrigation (PUI). The roots were grooved longitudinally and split into halves. Images of each half of the canal were evaluated by digital camera. It was found that neither syringe injection nor PUI methods was efficient in removing the inter-appointment root canal medicaments. Remnants of medicament were found in all experimental groups regardless of the vehicle use.[46]

Kamburoglu K, Kursun S, Yuksel S, Oztas B (**2011**) proposed the idea of simulating internal root resorption cavity by use of 0.5 mm diamond round bur after first splitting the teeth along the coronal plane.[47]

Rodig T, Hirschleb M, Zapf A, Hulsmann M **(2011)** compared ultrasonic irrigation with RinsEndo for the removal of calcium hydroxide and Ledermix paste from root canals. The root canals of sixty extracted single-rooted teeth were prepared using Flex Master rotary instruments to size 60, 0.02 taper. The roots were split longitudinally, and a standardized groove was prepared in the apical part of one segment. The teeth were randomly allocated into two groups (n = 30), according to the intracanal dressing. In the first group, grooves were filled with calcium hydroxide paste (Calxyl), whereas the grooves in the second group were filled with Ledermix paste. After reassembly, the root canals were completely filled with the respective medicament using a lentulospiral. The removal of medicament dressing was performed after 7 days with either passive ultrasonic irrigation or RinsEndo and 1% sodium hypochlorite for 3 min. The amount of remaining medicament was evaluated under OSM with 30X magnification. It was concluded that none of the irrigation techniques was able to completely remove the intracanal medicaments from the apical part of the root canal. Irrespective of the irrigation technique, significantly less Ledermix paste was detected compared with calcium hydroxide.[48]

Khaleel HY, Al-Ashaw AJ, Yang Y, Pang AH, Ma JZ **(2013)** compared calcium hydroxide removal by Endoactivator, ultrasonic and ProTaper file agitation techniques. Fifteen extracted single-rooted teeth were collected and used for all four groups. The samples were firstly prepared by ProTaper rotary instruments, and then sectioned longitudinally through the long axis of the root canals, followed by final reassembling by wires. Calcium hydroxide was kept in the canals for 7 days setting. The removal was done with 5 mL of 2.5% sodium hypochlorite (NaOCl) followed by 1 mL of 17% ethylenediamine tetraacetic acid and a final irrigation with 5 mL of 2.5% NaOCl solution for all groups. No additional agitation of the irrigant was performed in group 1, while agitation for 20 s between irrigants was done with F2 ProTaper rotary file in group 2, EndoActivator with tip size 25/.04 in group 3 and by an ultrasonic file 25/.02 in group 4. The total activation time was 60 s. The roots were then disassembled and captured by digital camera. Results showed that none of the four techniques could remove all calcium hydroxide. No significant difference was found between EndoActivator and ultrasonic techniques. However, they both removed significantly more calcium hydroxide than ProTaper and needle irrigation ($p=0.0001$). In conclusion, the sonic and ultrasonic agitation techniques were more effective in removing intracanal medicaments than the ProTaper rotary file and needle irrigation in all thirds of the canal.[49]

Yucel AC, Gurel M, Guler E, Karabucak B (**2013**) compared new irrigation systems with a conventional irrigation technique for the removal of inter-appointment calcium hydroxide. Forty-seven extracted human single-rooted teeth were instrumented, and $Ca(OH)_2$ paste was placed into root canals by using a lentulospiral at the apical third. Teeth were randomly divided into three groups according to different irrigation protocols using a 30-gauge slot-tipped needle, EndoVac system and ProUltra® PiezoFlow™ ultrasonic irrigation system. Scanning electron microscopic images of the selected root canal surfaces (cervical, middle and apical third) were evaluated using a 5-grade scale. The EndoVac and PiezoFlow groups demonstrated the lowest scale values (cleanest canals); however, there was no statistical difference between these two groups. The conventional irrigation group exhibited significantly higher scores ($p < 0.05$). The conventional needle irrigation was not sufficient to remove $Ca(OH)_2$ from the root canal system.[50]

Silveira PF, Vizzotto MB, Montagner F, da Silveira HL, da Silveira HE **(2014)** developed a new method for simulating internal resorption cavity by acid demineralization. Eleven extracted teeth were mesiodistally sectioned into two halves. The protocol used composed of 24 hour cycles (5 % nitric acid for 12 hours, rinsing with deionized water, and 8% sodium hypochlorite for 10 minutes). At the end of each cycle, one tooth was removed from the treatment and evaluated under electron microscope. Resorption by this protocol reproduced lesions of different sizes. The irregular shape and large diameter/depth ratio suggested that these lesions were more similar to in-vivo internal resorption, compared with bur-induced lesions.[51]

Manisha Laxmichand Kungwani, Krishna P. Prasad, Tushar Suresh Khiyani (**2014**) compared cleaning efficacy of EndoVac with conventional irrigation needles in debris removal from root canal. Fifteen matched pairs of single canaled vital teeth with mature apices indicated for extraction were selected. After working length determination and biomechanical preparation, the teeth in the right quadrant were irrigated with EndoVac system and with Max-i-Probe needles in the left quadrant using 3% NaOCl and 17% ethylenediaminetetraacetic acid. Teeth were extracted and marked at 1 and 3 mm from working length and decalcified in Kristenson's solution. Stained histologic slides were observed under trinocular research microscope. No statistical significant difference was found at 3 mm level between the groups. Teeth in EndoVac group had significantly less debris at 1 mm level. EndoVac was found to be better in removing debris from the apical thirds of root canals.[52]

Keles A, Ahmetoglu F, Uzun I (**2014**) used no 6 round diamond bur for creation of small hemi circular cavities to simulate internal root resorption in their study. They proposed that this technique produced more uniform, standardized form of cavities.[53]

Topcuoglu HS, Duzgun S, Ceyhanli KT, Akti A, Pala K, Kesim B **(2015)** evaluated the effect of different irrigation techniques in the removal of calcium hydroxide from an internal root resorption cavity. The root canals of 100 single-rooted teeth were prepared using the ProTaper system to size F5. The roots were split longitudinally, and standardized simulated internal root resorption cavities were prepared in the two root halves. The root halves were reassembled, and calcium hydroxide was placed into the root canals, with the exception of five teeth that served as the negative control group. Another five teeth (the positive control group) were not subjected to the calcium hydroxide removal procedure. Ninety teeth were randomly divided into six experimental groups (n = 15), according to the final irrigation techniques used: conventional syringe irrigation (CSI), Canal Brush (CB), passive ultrasonic irrigation (PUI), Self-Adjusting file.(SAF) system, EndoActivator (EA), and apical negative pressure irrigation (EndoVac system). Five milliliters of 3% NaOCl and 17% EDTA were used in all experimental groups during the calcium hydroxide removal procedure. The amount of remaining calcium hydroxide was evaluated under a Stereomicroscope at 20X magnification. Remnants of CH in simulated internal root resorption cavities were found in all experimental groups. SAF and PUI were superior to the other groups ($p <0.05$); however, there was no significant difference between the SAF and PUI ($p >0.05$). There were also no significant differences between the CSI, CB, EA and EndoVac groups ($p >0.05$).[54]

Ma JZ et al **(2015)** did micro-computed tomographic evaluation of the removal of calcium hydroxide medicament from C-shaped root canals of mandibular second molars. Thirty mandibular second molars, 15 in C1 and 15 in C2 configurations as first identified by µ-CT, were divided into three groups (five C1 and five C2 in each group) for the three irrigation methods. All teeth were prepared to ProTaper Universal F2 and filled with calcium hydroxide paste. The calcium hydroxide was removed with F2 files and irrigation without agitation or with agitation using either EndoActivator or ultrasonics. μ-CT was used to measure the initial amount of calcium hydroxide present. After removal of $Ca(OH)_2$, μ-CT imaging was used to assess the percentage of volume of residual calcium hydroxide in the canal. There was no significant difference in the mean volume of the root canal systems after instrumentation amongst the three groups. The three irrigation techniques left 2–17% of $Ca(OH)_2$ in the root canals after removal. The mean volume of the remaining $Ca(OH)_2$ was higher in the group without agitation than in the groups with sonic or ultrasonic agitation ($p < 0.05$). In the apical third, 68% of the canal space remained occupied by $Ca(OH)_2$ when no agitation was used, whereas 28% and 31% remained filled by $Ca(OH)_2$ in the EndoActivator and ultrasonic groups, respectively. There was no significant difference in the amount of residual $Ca(OH)_2$ between the EndoActivator and ultrasonic groups.[55]

Keskin C, Sariyilmaz E, Sariyilmaz O (**2017**) evaluated the effect of supplementary use of XP-endo Finisher file, passive ultrasonic activation (PUI), EndoActivator (EA), and Canal Brush (CB) on the removal of calcium hydroxide (CH) paste from simulated internal resorption cavities. The teeth were split longitudinally, and standardized internal resorption cavities were prepared with burs. XP-endo Finisher and PUI removed significantly more CH than CSI, EA, and CB ($p < .05$), showing no significant difference between them ($p > .05$). Differences among CSI, EA, and CB were also non-significant ($p > .05$).[56]

D S Kirar, Pradeep Jain, Pallav Patni **(2017)** compared different irrigation and agitation methods for the removal of two types of calcium hydroxide medicaments from the root canal walls. The samples were divided into 4 groups. Group 1 (n=20) were filled completely with water based calcium hydroxide (CH), Group 2 (n=20) were filled with oil based CH using lentulospiral, Group 3 (n=5) - the positive control group received the CH as intracanal medication, but no subsequent removal, Group 4 (n=5) - the negative control did not receive CH placement. Further on, Group 1 and Group 2 were divided into four sub-groups (n=5). They were divided into 4 subgroups according to the use of conventional syringe, Manual Dynamic Agitation, Endoactivator and passive ultrasonic irrigation. Roots were split longitudinally into mesial and distal halves. Digital images of the root canal walls were acquired by a Dental Operating Microscope (DOM) and assessed. Statistically significant differences were not found between the experimental groups and the negative group in any one third of the root canal ($p > 0.05$). However, a difference did exist between the experimental groups and the positive control group ($p < 0.05$). None of the experimental groups totally removed CH substances from root canal walls. Removal of CH was best achieved by sonic agitation using Endoactivator followed by passive ultrasonic irrigation (PUI), Manual Dynamic Agitation and conventional syringe irrigation with side-vented needle.[57]

MATERIALS AND METHOD

MATERIALS & METHOD

Hundred single rooted human maxillary anterior teeth were collected, cleaned, disinfected and handled as per the recommendations and guidelines by OSHA & CDC.[58] Approval from Institutional Ethical Committee was obtained for the study. Each tooth was examined under Stereomicroscope (10X, 3D Medical System) so as to check for cracks or surface defects.

SELECTION CRITERIA:

Inclusion criteria:

- Non carious teeth
- Teeth with single root and single canal.

Exclusion criteria:

Teeth excluded from the study were:

- Teeth with evident root fracture.
- Teeth with extreme calcifications and canal curvatures.
- Teeth with developmental anomalies.
- Teeth with incompletely formed apices.

ARMAMENTARIUM:

Instruments and Equipments:

- Straight probe (GDC, India) (PLATE II)
- Explorer (GDC, India) (PLATE II)
- Tweezers (GDC, India) (PLATEII)
- Hand Scaler (Satelec P5 Newtron Worktop Scaler, Satelec Acteon)
- Cotton holder (GDC, India) (PLATE II)
- Waste receiver (GDC, India) (PLATE II)
- Digital Vernier Calliper (Workzone, Germany) (PLATE II)
- High speed air-rotor hand piece (NSK, Japan) (PLATE II)
- Contra angle micromotor hand piece (NSK ,Japan) (PLATE II)
- Round burs (Mani, Japan) (PLATE III)
- Double sided diamond disk (DFS, Germany) (PLATE III)
- Chisel and Mallet (Orthomax, India) (PLATE III)

- X-Smart Endomotor (Dentsply, Maillefer, Ballaigues, Switzerland) (PLATE III)
- Digital Radiovisiography System (Kodak 5100 RVG, France)
- Gates-Glidden drills (Mani, Japan) (PLATE IV)
- Standard 2% K files # 10, 15 & 20 , 21 mm (Sybron Endo , USA) (PLATE IV)
- Endo Bloc (Dentsply, Maillefer, Ballaigues, Switzerland) (PLATE III)
- 5ml syringe with 27 gauge side vented needle (Nirlife, India) (PLATE IV)
- ProTaper Universal files - 25mm (Dentsply, Maillefer, Ballaigues, Switzerland) (PLATE IV)
- Canal Brush (Coltene/Whaledent, Germany) (PLATE IV)
- EndoVac (Discus dental LLC, California) (PLATE IV)
- Thermocycling unit (LG, India) (PLATE VII)
- Stereomicroscope (3D Medical System, India) (PLATE IX)

Materials:

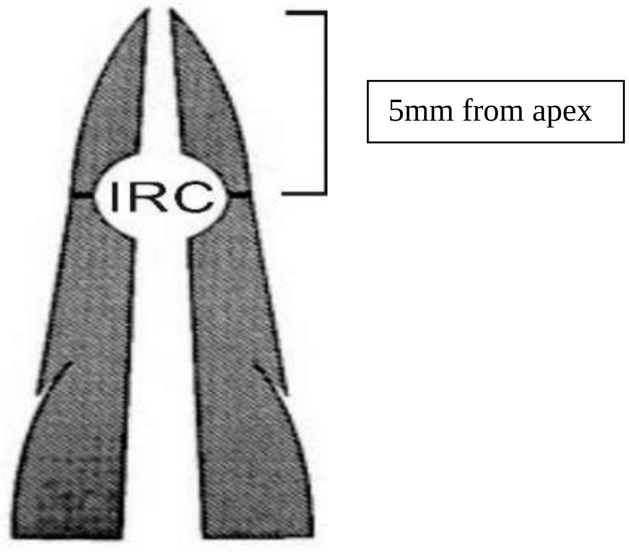
- Root canal irrigation solution
  - 5.25% Sodium Hypochlorite (Hyposept UPS Hygiene, India) (PLATE V)
  - Normal saline (0.9 % w/v, Nirlife, India) (PLATE V)
  - 17% Liquid EDTA (Prime Dental, India) (PLATE V)

- Chelating agent for smear layer removal
    - 17 % EDTA (Prime Dental, India) (PLATE V)
- Absorbent points (Diadent, Korea) (PLATE V)
- ProTaper F5 Gutta-percha points (Diadent, Korea) (PLATE V)
- Flexkwik (Pidlite Industries Ltd, India) (PLATE V)
- Cavit (3M ESPE, Germany) (PLATE V)
- Calcium hydroxide (Avuecal, Prime dental, India) (PLATE V)
- Phosphate buffer saline solution (Severn Biotech)

All the samples were radiographed with Kodak 5100 RVG system (Kodak, France) to eliminate the presence of any abnormality. The selected teeth were stored in Phosphate Buffer Saline Solution (Severn, Biotech). During all stages of the study, dehydration of the specimens was avoided.

PREPARATION OF SAMPLES:

All the samples were sectioned in coronal portion with a double sided diamond disc (DFS, Germany) to obtain a standardized length of 20mm. Canal orifices were enlarged with Gates-Glidden drills (Mani, Japan) using sizes 1-3 in descending order. A 15 no. K-file (Sybron Endo, USA) was used to establish apical patency. When the file tip appeared at the apical foramen, the length of the file was recorded; the working length was determined to be 1 mm short of the measured length. Instrumentation was performed with a crown-down technique using ProTaper nickel-titanium rotary instruments (Dentsply, Maillefer, Ballaigues, Switzerland) at determined working length. All the canals were enlarged up to F5. During preparation and between each file, 3 ml of 5.25% sodium hypochlorite (Hyposept UPS Hygiene, India) was used as irrigant. After completion of the preparation, the root canals were irrigated with 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) (Prime Dental, India) for 1 min and 5 mL of 5.25% NaOCl for 1 min. The canals were finally rinsed with 10 mL of distilled water and then dried with absorbent points (Diadent, Korea). A guide mark was placed on the buccal surface of sectioned tooth using carborundum disk (DFS, Germany). The roots were sectioned using a diamond disc attached to Contra angle micromotor handpiece (NSK, Japan) and further separated using a chisel (Orthomax, India) in a buccolingual direction. Hemi-circular cavities were created within the canal using a Contra angle micromotor handpiece (NSK, Japan) and BR-31 no round diamond bur (Mani, Japan) at about 5mm from the apex. A small drop of glue (Flexkwik, Pidlite Industries Ltd, India) was carried with the help of a dental explorer and spread carefully on the sectioned parts of tooth. Then, by pairing the guide mark, the corresponding sections were cemented. The root canals of teeth were filled with calcium hydroxide paste (Avuecal, Prime dental). The access cavities were sealed with a temporary filling material (Cavit, 3M ESPE, Seefeld, Germany).All the samples were then subjected to thermocycling (LG, India) to mimic the oral condition.



Hemi-circular cavities were created at about 5mm from the apex

DISTRIBUTION OF STUDY GROUPS:

Depending upon the technique of removal of calcium hydroxide, the samples were randomly divided into five groups as follows:

GROUP	SAMPLE DISTRIBUTION	NO OF SAMPLES
Group I	Control group (No removal technique employed)	20
Group II	Removal of calcium hydroxide by conventional syringe irrigation	20
Group III	Removal of calcium hydroxide by Manual Dynamic Agitation	20
Group IV	Removal of calcium hydroxide by Canal Brush	20
Group V	Removal of calcium hydroxide with EndoVac System	20

In control group, no removal of calcium hydroxide was done.

EXPERIMENTAL GROUPS AND IRRIGATION PROTOCOL

Group II: Conventional syringe irrigation (CSI) group

In this group, irrigation was performed with 5 mL of 5.25% NaOCl (Hyposept UPS Hygiene, India) for 1 min, then rinsed with normal saline (Nirlife, India) followed by irrigation with 5mL of 17% EDTA (Prime Dental, India) for 1 min, using a syringe and a 27-gauge side vented needle (Nirlife, India) placed 1 mm short of the WL. No agitation of irrigants was performed.

Group III: Manual Dynamic Agitation group

Manual dynamic agitation was carried out using 5 ml of 5.25% NaOCl (Hyposept UPS Hygiene, India) for 1 min with short push–pull strokes using ProTaper F5 Gutta-percha (Diadent, Korea) followed by rinsing with normal saline (Nirlife, India); 5ml of 17% EDTA (Prime Dental, India) was used for 1 min with short push–pull strokes using the same gutta-percha cone. Delivery of the irrigants was performed by inserting a side-vented 27-gauge side vented needle to 4 mm coronal of the working length. All push–pull strokes of the gutta-percha cone were performed manually at an approximate rate of 100 strokes per min.

Group IV: Canal Brush (CB) group

In this group, irrigation was performed with 5 mL of 5.25% NaOCl (Hyposept UPS Hygiene, India), then rinsing was done with normal saline (Nirlife, India) followed by 5mL of 17% EDTA (Prime Dental, India). Agitation of irrigants was accomplished using a medium variety of Canal Brush with a tip diameter of 0.30 mm (Coltene/Whaledent, Germany) in an Endomotor (Dentsply, Maillefer, Ballaigues, Switzerland) set at 600 rpm. The Canal Brush was activated for 1 min for each solution used. The brush was used with a gentle up-and-down motion at 1 mm from the WL. One Canal Brush per root was used.

Group V: EndoVac group

In this group, the apical negative pressure irrigation (EndoVac) was used. The EndoVac system (Discus dental LLC, California) was used with 5 mL 5.25% NaOCl (Hyposept UPS Hygiene, India) followed by rinsing with normal saline (Nirlife, India) and then 5 mL 17% EDTA (Prime Dental, India). The irrigant was delivered with macrocannula tip in up and down motion for 30 s. This was followed by three cycles of microcannula irrigation. For each cycle of irrigation with microcannula, tip was placed at full WL for 6s and then withdrawn 2mm from full WL for 6s. This was repeated five times during a period of 30 s.

Upon completion of the respective irrigation protocol, the canals were rinsed with sterile saline and dried with multiple paper points.

SAMPLE PREPARATION FOR STEREOMICROSCOPIC ANALYSIS

After completion of irrigation protocol, the two halves of tooth were separated and evaluated under Stereomicroscope (Image Analysis System, chroma system make, model no-MVIG2005) for calculating the amount of remaining calcium hydroxide after removal.

ALGORITHM OF METHOD

100 Extracted maxillary anterior teeth

↓

Shaping and cleaning was performed on each tooth using rotary ProTaper instruments

↓

Longitudinal sectioning of tooth followed by creation of internal resorption cavity.

↓

Recementation of the sections and placement of calcium hydroxide medicament

↓

Distribution of study groups depending upon the technique of removal of calcium hydroxide

↓

GROUP I	GROUP II	Group III	GROUP IV	GROUP V
Control group without irrigation	Control group with conventional syringe irrigation	Active irrigation with Manual Dynamic Agitation	Active irrigation with CanalBrush	Irrigation with EndoVac system

↓

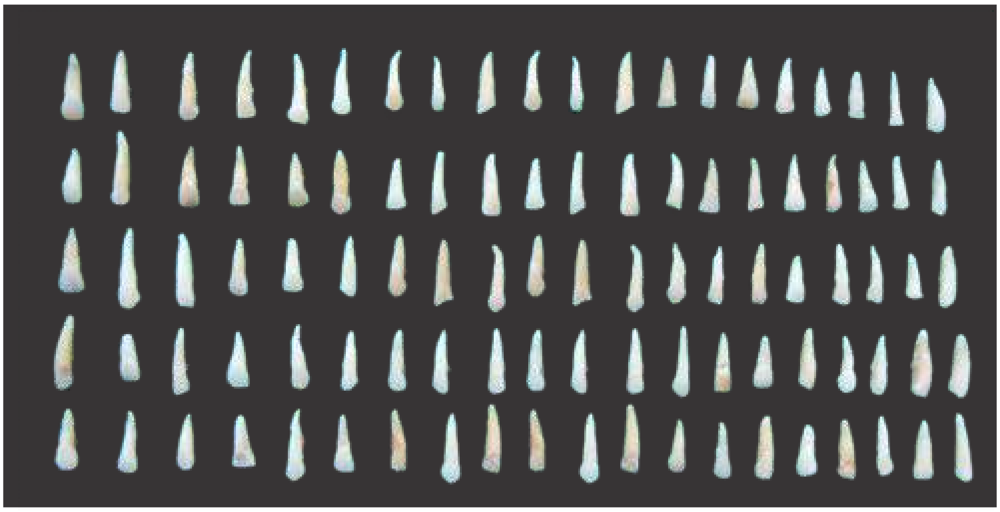
Samples were separated using a chisel in buccolingual direction

↓

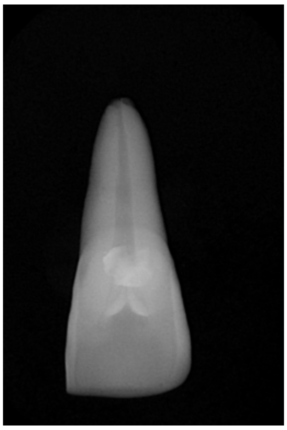
Evaluation under Stereomicroscope to calculate the remaining calcium hydroxide on root canal wall

PLATE - I

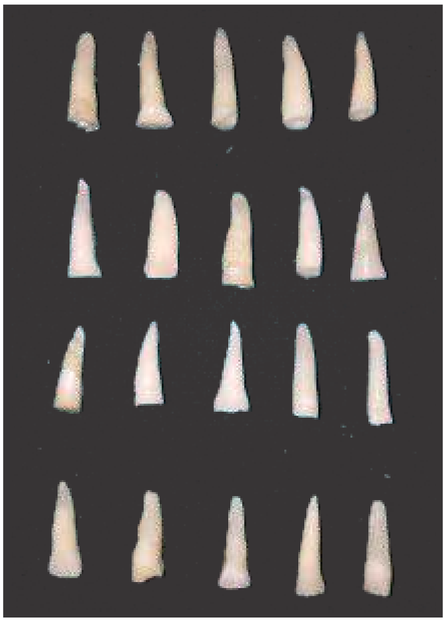
SAMPLE COLLECTION



Total Samples(N=100)



Pre Operative Radiographs



Teeth per Group (n=20)

PLATE - II

ARMAMENTARIUM

Hand instruments
(GDC, India)

Cotton Holder & Waste receiver
(GDC, India)

Digital Vernier Caliper
(Workzone tools, Germany)

Contraangle Micromotor Handpiece
(NSK, Japan)

High speed Air Turbine
(NSK, Japan)

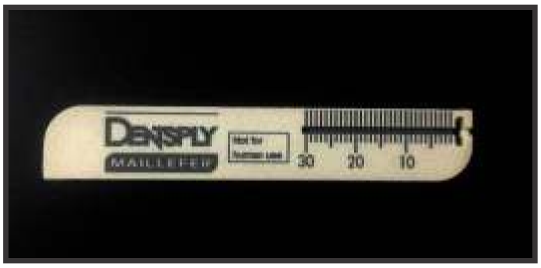
PLATE - III

ARMAMENTARIUM

Double sided Diamond Disc
(DFS, Germany)

Chisel Mallet
(Orthomax, India)

Endodontic Motor X-Smart
(DENTSPLY, Maillefer, Ballaigues, Switzerland)

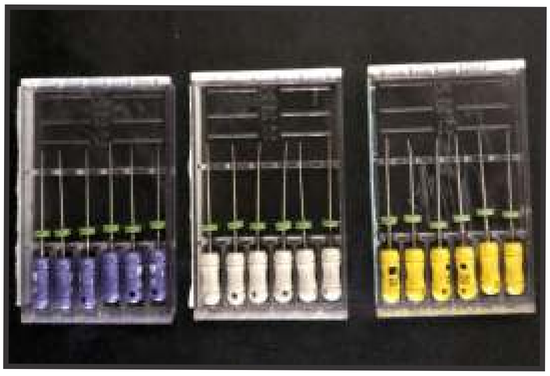


Endobloc
(DENTSPLY, Maillefer, Ballaigues, Switzerland)

Diamond burs
(Mani, Japan)

PLATE - IV

ARMAMENTARIUM



Standard 2% K files# 10,15 & 20, 21mm
(Sybron Endo, USA)

Pro Taper Rotary System-25 mm
(DENTSPLY, Maillefer, Ballaigues, Switzerland)

GG Drill,
(Mani, Japan)

Syringe
(Nirlife, India)

Roeko Canal Brush,
(Coltene/Whaledent, Germany)

Endo Vac assembly
(Discus dental LLC, California)

PLATE - V

MATERIALS

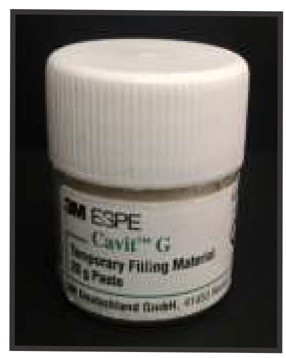
Sodium Hypochlorite
(Hyposept UPS Hygiene, India)
0.9%w/v Normal Saline
(Nirlife, India)

Dent wash 17% Liquid EDTA
(Prime dental, India)

RC Help 17% EDTA Chelating gel
(Prime dental, India)

Avuecal
(Dental Avenue, India)

Flexkwik,
(Pidlite Industries Ltd, India)



Cavit G
(3M ESPE, Germany)

Absorbent points
(Diadent, Korea)

Pro Taper F5 GP
(Diadent, Korea)

PLATE - VI

PREPARATION OF SAMPLES

Decoronation of sample

Standardised length-20mm

Access opening with no 2 round bur

Working length determination

Biomechanical preparation till F5 Rotary ProTaper file

Irrigation of samples

PLATE - VII

PREPARATION OF SAMPLES

Sectioning of samples

Sectioned samples

Making internal resorption cavity

Sticking two parts together

Avuecal placement

Thermocycling of samples

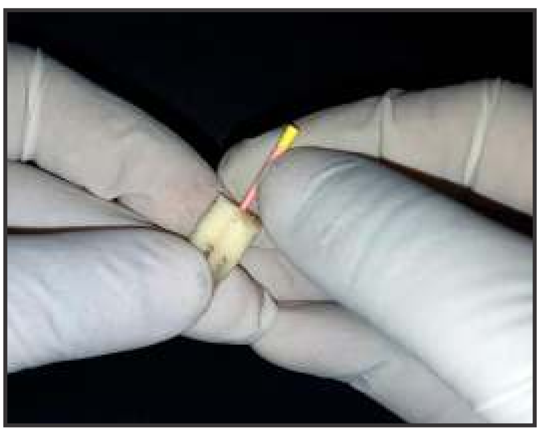
PLATE - VIII

PREPARATION OF SAMPLES

Irrigation with NaOCl

Irrigation with 17%EDTA liquid

Using Conventional Syringe



Using Manual Dynamic Agitation

Using Canal Brush

Irrigation using macrocannula

Irrigation using microcannula

Using EndoVac

PLATE - IX

EVALUATION UNDER STEREOMICROSCOPE

Mounting Under Stereomicroscope

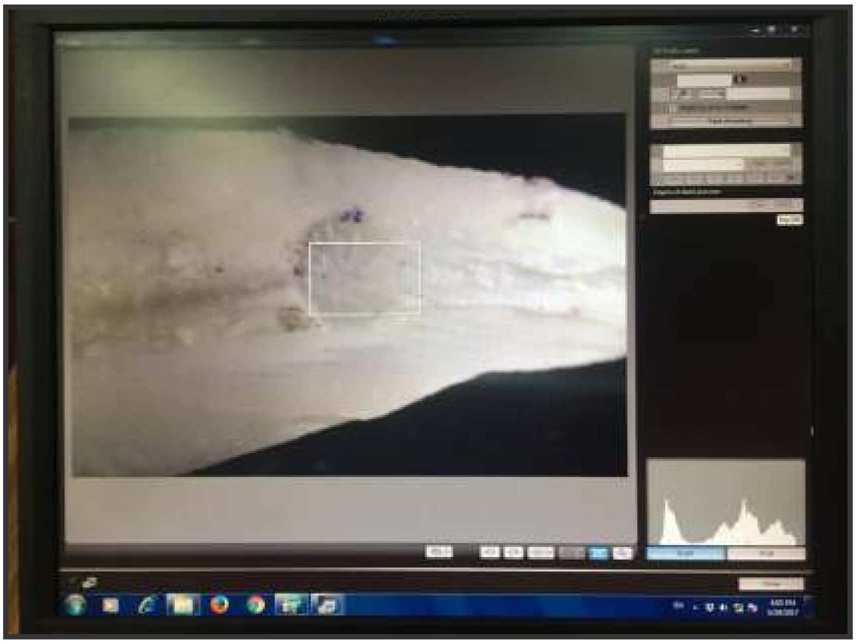


Image Analysis

PLATE - X

STEREOMICROSCOPIC IMAGES

GROUP - I
(CONTROL)

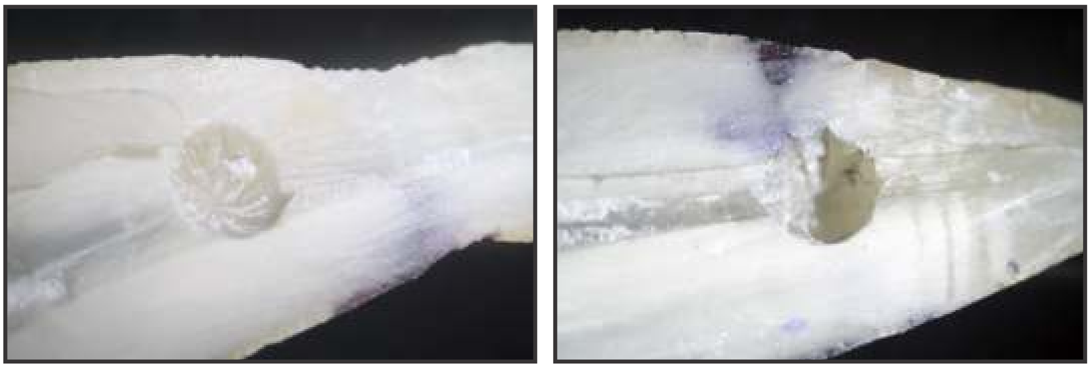
GROUP - II
(CONVENTIONAL SYRINGE)

GROUP - III
(MANUAL DYNAMIC AGITATION)

PLATE - XI

STEREOMICROSCOPIC IMAGES

GROUP - IV
(CANAL BRUSH)



GROUP - V
(ENDOVAC)

RESULTS

RESULTS

The aim of the present study was to evaluate the efficacy of conventional syringe, Manual Dynamic Agitation, Canal Brush and EndoVac in removing calcium hydroxide from an experimental internal resorption cavity. 100 Human maxillary single rooted extracted teeth were collected and divided into 5 groups as follows:-

SERIAL NO	NAME OF THE GROUP	NO OF SAMPLES
1	Control	20
2	Conventional syringe	20
3	Manual Dynamic Agitation	20
4	Canal Brush	20
5	EndoVac	20

Samples from all the groups were prepared for Stereomicroscopic analysis under 10X magnification. The results were recorded by Image Analysis System, Chroma Systems Pvt. Ltd, India, Model: MVIG 2005.

STATISTICAL ANALYSIS

The data on percent of calcium hydroxide remaining in the internal resorption cavity was obtained for samples in all the four study groups and control group. Descriptive statistics like mean, median, standard deviation, minimum and maximum of outcome i.e. percentage of calcium hydroxide remaining were obtained for each group. (Table 1; Graph 1). The statistical comparison of the outcome variable was performed using Kruskal-Wallis test. (Table 2) Further, pair wise comparison of groups was performed using Wilcoxon rank sum test. (Table 3) All the analyses were performed using SPSS ver 20.0 (IBM Corp.) software and the statistical significance was evaluated at 5% level.

The description of statistical tests used is as under:

Kruskal-Wallis test – A non-parametric equivalent of ANOVA

The test is a non-parametric equivalent of one-way analysis of variance for comparing three or more groups. It is used for testing when the samples originate from same or different populations. The procedure for determining significance of difference across groups using the test is as below:

i) The n_1, n_2, …,n_k observations from k samples are combined into a single series of size n and arranged in order of magnitude from smallest to largest. The observations are then replaced by ranks from 1 assigned to smallest observation to n assigned to largest observation. When two or more observations have same value, each observation is given a mean of the ranks for which it is tied.

ii) The ranks assigned to observations in each of the k groups are added separately to give *k* rank sums.

iii) The test statistic is defined as:

$$H = \frac{12}{n(n+1)} \sum_{j=1}^{k} \frac{R_j^{\,2}}{n_j} - 3(n+1)$$

where k is the number of groups; n_j is the number of observation in j^{th} group; *n* is the total number of samples from all the groups and R_j is the sum of ranks from j^{th} group.

iv) When there are more than 5 observations in one or more groups, H is compared with the tabulated value of χ^2 with *k*-1 degrees of freedom.

Wilcoxon rank sum test - A non-parametric equivalent of Student's t-test

The test is a non-parametric equivalent of Student's t-test for independent samples, when the assumption of normality is violated. It evaluates the null hypothesis that the two populations are the same against alternative that particular population has larger values than the other. It involves computation of a test statistics based on ranked series. The observations are ranked according to magnitude irrespective of the two groups. The steps involves are as under:

i) Add the ranks for observations from group 1.

ii) Since sum of all ranks equal $N\,(N+1)/2$, the sum of ranks in group 2 is total sum minus the sum of group 1.

iii) A statistic U is defined as:

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2}$$

where n_1 is the size of sample 1 and R_1 is the sum of ranks of sample 1. Equally valid formula for U is

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2}$$

The smaller of U_1 and U_2 is for significance testing.

For large sample sizes ($N > 30$), U is approximately normally distributed, and the standardized value is given by

$$z = \frac{U - m_U}{\sigma_U}$$

where m_U and σ_U are the mean and standard deviation of U. The significance of z can be obtained from normal probability tables. Here m_U and σ_U are given by:

$$m_U = \frac{n_1 n_2}{2}\ ;\ \sigma_U = \sqrt{\frac{n_1 n_2(n_1+n_2+1)}{12}}$$

Table 1 and Graph 1 show the mean value for percent of calcium hydroxide remaining in the internal resorption cavity in the five study groups. The mean for control group is the highest with a value of 99.87%±0.32%. It is followed by the conventional syringe group, the Manual Dynamic Agitation group and the Canal Brush group with mean values of 83.58%±9.38%, 45.54%±9.64% and 24.25%±6.80% respectively. EndoVac group has the minimum mean value of 6.21%±5.77%.

Table 2 shows comparison of percentage of calcium hydroxide remaining in the internal resorption cavity according to study groups. A comparison of percent of calcium hydroxide remaining in the internal resorption cavity was carried out across study groups using the Kruskal-Wallis test. The difference obtained across five groups was statistically highly significant with p-value < 0.0001. Hence, pair-wise analysis was performed using Wilcoxon rank sum test.

Table 3 reveals that the difference of percentage of calcium hydroxide remaining in the internal resorption cavity between any pair of groups using Wilcoxon rank sum test. It was statistically highly significant with p-value < 0.0001 for all the pairs. The control group had the maximum calcium hydroxide remaining (99.87%), which was significantly higher than all the other groups. For conventional syringe, the percent remaining was 83.58%, which was significantly lower than control; however, significantly higher than other groups. With Manual Dynamic Agitation, 45.54% calcium hydroxide was remaining, which was significantly lower than control and conventional syringe; however, higher than other techniques. Canal Brush method resulted in 24.25% of remaining calcium hydroxide which was significantly lower than Manual Dynamic Agitation; however, it was significantly higher than EndoVac. The percentage of calcium hydroxide remaining for EndoVac was the least i.e. 6.21%, which was significantly lower than all the other methods; and thus it emerged out to be the best technique for calcium hydroxide removal.

DISCUSSION

DISCUSSION

The main goal of endodontic treatment is the prevention and treatment of lesions of endodontic origin. Successful endodontics is based on the triad i.e. correct diagnosis, biomechanical preparation and three- dimensional obturation. Most of the failures of root canal treatment occur due to inadequate cleaning and improper obturation of the root canal system. Both these factors are limited by the presence of anatomical challenges like lateral canals, apical ramifications, fins, isthmus and pathologic irregularities like internal resorption defect.[59]

Root resorption is the loss of dental hard tissues as a result of clastic activities that might occur as a physiologic or pathologic phenomenon. Internal resorption (IR) is an insidious and rare resorptive pathological process that begins within the pulp space and may extend into the surrounding sound dentin. According to the location in which the condition is observed, it can be of two types: intraradicular and apical. Intraradicular internal resorption is purely an inflammatory condition, resulting in progressive destruction of intraradicular dentin along the middle and apical third of the canal walls.[60] The resorptive spaces might be filled by granulation tissue only or in combination with bone-like or cementum-like mineralized tissues. The condition is more frequently observed in male than female subjects.[61] Although intraradicular internal root resorption is a relatively rare clinical entity even after traumatic injury, a higher prevalence of the condition has been associated with teeth that had undergone specific treatment procedures such as autotransplantation. Haapasalo suggested a prevalence of 0.01%–1% for internal root resorption occurring due to inflammatory causes.[60] Wedenberg and Zetterqvist reported that there was no clinical or morphological difference in internal resorption between primary and permanent teeth, although the resorption progressed more rapidly in primary teeth.[62]

To date, root canal treatment remains the only treatment of choice for teeth diagnosed with internal root resorption. The resorptive defect is the result of an inflamed pulp and the clastic precursor cells that are predominantly recruited through the blood vessels. Conventional root canal therapy controls the process of internal root resorption by severing the blood supply to the resorbing tissues.[10] However, due to irregular nature of the lesion, chemomechanical debridement of the root canal space alone fails to consistently render the root canal system bacteria-free. Thus, an intracanal, antibacterial medicament should be used to improve disinfection of the inaccessible root resorption defects.[9]

A medicament is an antimicrobial agent that is placed inside the root canal between treatment appointments in an attempt to destroy remaining microorganisms and prevent reinfection.[63] Walton clearly stated that "Intracanal medicaments have traditionally gone hand-in-glove with endodontics. They are generally considered to be an integral part of treatment and important to the success of root canal therapy."[64]

Medicaments may be utilized in endodontics[65] as they:

1. Help eliminate bacteria.
2. Reduce inflammation (and thereby reduce pain).
3. Induce healing of calcified tissues.
4. Help eliminate apical exudate.
5. Control inflammatory root resorption.
6. Prevent contamination between appointments.

Several authors have stressed the importance of using intra-canal medicaments in order to achieve bacteria-free canals in a predictable manner.[66] Langeland has stated that if necrosis is established in the root canal, then the success and long-term prognosis will depend upon the elimination of bacteria from the dentinal tubules.[67]

The ideal root canal medicament should have the following properties: [68]

1. Anti-bacterial.
2. Anti-inflammatory.
3. Ability to stimulate hard tissue repair.

4. Ability to prevent or reduce pain.

5. Non-irritant to the periapical and periodontal tissues

6. Ability to diffuse through dentine.

7. Quick acting initially.

8. Long lasting.

9. Effective in the presence of pus and organic debris

10. Water soluble.

11. Practical to use (easy to place and remove).

12. Non-staining to the tooth and soft tissues.

13. Inexpensive.

14. A long shelf-life.

Many materials have been used as root canal medicaments throughout the past century. They include paraformaldehyde, parachlorophenol, camphorated para-monochlorophenol (CMCP), formocresol, cresol, creosote, thymol, eugenol, metacresylacetate, NaOCl, various iodine compounds, quarternary chlorine compounds, quarternary ammonium compounds, Cresophene, Ledermix paste, Septomixine Forte paste, Pulpomixine paste, Triple antibiotic paste and Calcium hydroxide.[68]

Calcium hydroxide is one of the most extensively used intracanal medicament since its introduction by Hermann in 1920. Its history of use over a long period of time in the endodontic field has established its safety.[68] Calcium hydroxide has been shown to effectively eradicate bacteria that persist after chemomechanical debridement.[69] The ability of calcium hydroxide to dissolve necrotic tissue is useful, as anatomical problems often make it difficult for irrigating solutions to reach all areas of the root canal. Studies have also shown that calcium hydroxide when used as an adjunct with sodium hypochlorite, the canal was cleaned as effectively as when ultrasonic instrumentation was used.[70] Nevertheless, some case reports demonstrated the inability of calcium hydroxide to eliminate bacteria in ramifications because of its low solubility and inactivation by dentin, tissue fluids, and organic matter.[71] Despite these limitations, the use of multiple calcium hydroxide dressings has been advocated to enhance chemomechanical debridement of the internal root resorption defect.[10]

$Ca(OH)_2$ placed as a medicament has to be removed before the canal is obturated. Laboratory studies have revealed that remnants of $Ca(OH)_2$ can hinder the penetration of sealers into the dentinal tubules,[17] hinder the bonding of resin sealers to dentine,[45] increase the apical leakage of root fillings, potentially interact with zinc oxide eugenol sealers and make them brittle and granular. Accelerated rate of setting of sealers is also noted.[16] Residual calcium hydroxide also interferes with accuracy of apex locator.[72] Therefore; all interappointment dressings have to be removed from the root canal prior to obturation to avoid the negative interference between medicament and material, which may result in increased apical leakage.

Several techniques have been proposed to remove the $Ca(OH)_2$ dressing from the root canal system, including the use of endodontic hand files, sonic activation, passive ultrasonic irrigation, the Canal Brush System, and nickel titanium (NiTi) rotary instruments.[18,43,73] The most commonly described method for removing $Ca(OH)_2$ is instrumentation with the use of a "master apical file"(MAF) at working length (WL) along with sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) irrigant solutions.[18] However, there is still no consensus as to which is the best method for removal.

Thus the current study was conducted which aims to evaluate the effectiveness of 4 different techniques i.e. conventional syringe irrigation, Manual Dynamic Agitation, Canal Brush and EndoVac in removal of calcium hydroxide from a pathologic defect i.e. internal resorption cavity.

Traditionally, the most common way in which the irrigant has been introduced into the root canal was through needle connected to a syringe.[74] Among the various needle tip designs, the safe ended needles have shown better results and long-term clinical success. These needles have side port dispersal and a rounded tip. The side port dispersal design produces upward flushing motion for complete canal irrigation.[75] For this reason, the safe ended needles were selected in our study.

Manual Dynamic Agitation is a cost effective technique used for effective cleaning of root canal system. This involves application of short, gentle strokes of the master cone to hydrodynamically displace and activate the irrigant (McGill et al.).[21] Gu et al. hypothesized that this technique may be useful in breaking the air bubble located at the apical 0 –2 mm of the canal. This creates enough flow of irrigant to remove debris from the canal system.[23]This is a highly economic chairside technique with no study on its effectiveness of removing intracanal medicament from internal resorption cavity.

The Canal Brush (Roeko Canal BrushTM, Coltene/Whaledent, Langenau, Germany) is an endodontic microbrush introduced for root canal irrigation. This highly flexible microbrush is molded entirely from polypropylene and can be used both manually and in rotary motion.[22] Canal Brush when attached to contra angle handpiece is more efficient than manual one. [23] Thus rotary Canal Brush has been used in the present study. Canal Brushes are available in 3 different sizes- small, medium and large. A minimum of 30/0.04 preparation is needed for using medium variety of Canal Brush.[22] This variety was used in this study.

EndoVac is an irrigation system that works on the principle of apical negative pressure. It has three components: The Master Delivery Tip, MacroCannula and MicroCannula. The Master Delivery Tip is connected to a syringe of irrigant which delivers the irrigants and it also consists of an evacuation hood, connected via tubing to high speed suction of dental unit for simultaneous evacuation of the irrigants, thus preventing the overflow of irrigants into the pulp chamber. The plastic macrocannula has a size 55 open end with a .02 taper and is attached to a titanium handle for gross, initial flushing and evacuation of the coronal and middle part of the root canal. Stainless steel microcannula (size 32) has 4 sets of 3 laser-cut, laterally positioned, offset holes adjacent to its closed end and is used in canals enlarged upto size 35 or larger. The MacroCannula or MicroCannula is connected to the high-speed suction of dental unit, thus simultaneously creating an apical negative pressure by supply of fresh irrigants in the chamber via cannula, and out through the suction hose. As a result, fresh irrigants are being constantly supplied to working length. Apical negative pressure has been shown to enable irrigants to reach the apical third and help overcome the issue of apical vapor lock.[44]

In the present study, maxillary anteriors were selected which are supposed to be having highest incidence of internal resorption defects. It has been documented that the process is initiated by a variety of stimuli such as trauma, pulpotomy, extreme heat produced during cutting of dentin, chronic inflammation of the pulp following caries perpetuated by bacterial factors, cracked tooth, tooth transplantation, and orthodontic treatment.[76, 77, 78, 79] Trauma is the most common etiological factor (43%), followed by carious lesions (25%). Maxillary anteriors are more prone to traumatic injuries being the cause for highest incidence.[77] Also anterior teeth have wide canals and thus roots can be easily split through the canals.

According to study by Topcuoglu HS, the passive ultrasonic irrigation showed maximum i.e. 50% tooth with complete removal of $Ca(OH)_2$, while CSI showed lowest i.e. 13% of tooth with complete removal of $Ca(OH)_2$. Assuming that similar differences could be obtained in the proposed study, the estimated sample size that can provide 95% confidence and 80% power is 20 samples per group.

100 extracted human maxillary anterior teeth were cleaned and stored in phosphate-buffered saline not more than 12 weeks as suggested by Jameson MW et al (1994)[80]**.** They observed that storage media and time of the specimen storage affect the fracture resistance of the tooth after extraction due to water loss with dehydration of dentine. Phosphate-buffered saline shows the best compatibility in maintaining the hydration of the extracted teeth.

The sectioning of tooth was done at predetermined distance i.e. 20mm from the apex to attain the standardization and uniformity in location of internal resorption cavity. Sectioning at this distance also provides coronal reservoir for more effectiveness of the irrigant solution.[54]

Shanmugaraj M et al described one of the methods of measuring working length on extracted teeth by inserting endodontic file into the root canal until the tip of the file was just visible at the apical foramen. The stopper was adjusted to the reference point and the file was just withdrawn. The canal length was determined and actual working length was established by deducting 1mm from this length, these readings were registered as actual working length.[81] This method was followed in the present study.

A Dafalla A et al found that NiTi rotary files prepare canals more rapidly, and shows low incidences of blockage, and only limited loss of working length. Canal preparation with K-file was time consuming and showed higher incidence of deformed instruments probably due to low elasticity of the stainless steel metal.[82] Ida de Noronha de Ataid et al concluded that Nickel-titanium rotary instruments demonstrate a superior quality of canal preparation compared to stainless steel K files, with respect to canal cleanliness, canal transportation and canal shape. ProTaper rotary instruments demonstrated a comparatively better quality of canal preparation in the apical region of teeth.[83] Therefore in the present study; the root canals were prepared by Pro Taper rotary instruments.

Baumgartner J C and Ibay AC in 1987 investigated the ability of several irrigating solutions to physically clean the root canal walls when used during mechanical instrumentation with a scanning electron microscope. They found that when used alone; neither NaOCl nor EDTA was totally effective in removing debris.

However, when the two solutions were used sequentially the canal walls were left free of debris. The combination of these solutions was considered as effective means of removing both organic and inorganic matter from the root canal. The smear layer was completely removed from the canal walls which left the dentinal tubules open.[84] These properties help to achieve bacteria-free root canal systems completely free of debris prior to placing a root canal filling. Thus both the irrigants have been used in the study with intermittent use of saline.

Punia S K et al demonstrated new method of sectioning where sectioning was done longitudinally by first creating a groove on both buccal and lingual surface with the help of diamond disc and then further separation using chisel to avoid any loss of material. This method has been employed in the present study to advocate minimal loss of tooth structure.[85] Kenee et al. (2006) reported that longitudinal sectioning might more accurately allow for the measurement of the complete canal area.[86] By splitting the roots in this way, the canals were confirmed to be free of debris before each removal technique was applied. Thus longitudinal sectioning was employed for the present study.

After sectioning, the cavities were prepared at 5 mm from apex as the internal resorption cavities are supposed to be located mostly in the middle and apical third of root of maxillary anteriors.[77]

Kamburoglu et al[47], Keles et al[53] suggested use of bur for creation of internal resorption cavity whereas Silveira et al[51] used acid demineralization technique for the same. Though, acid demineralization technique generates irregular lesion as present clinically but there is lack of standardization. Thus we have used burs for creation of internal resorption cavity to obtain standard uniform, well-characterised cavities.

Tasdemir T et al used wires for reapproximation of the sections of the teeth in their study.[87] Topcuoglu et al used glue for the reapproximation of two sections.[54] Glue has been used in the present study as it allows relatively better leakage proof approximation compared to wire.

$Ca(OH)_2$ has an active influence on the local environment around a resorptive area by reducing osteoclastic activity and stimulating repair (Tronstad et al. 1981). This function is attributed to pH of calcium hydroxide. Shaping and cleaning with only irrigating solutions did not inactivate the endotoxin; however, the same treatment along with the use of the $Ca(OH)_2$ medicament was found to be effective in the inactivation of the toxic effects of the endotoxin.[11] Jiang et al. (2003) also evaluated the direct effects of LPS on osteoclastogenesis and the capacity of $Ca(OH)_2$ to inhibit the formation of osteoclasts stimulated by endotoxin. They reported that $Ca(OH)_2$ significantly reduced osteoclast differentiation.[41] Thus $Ca(OH)_2$has been used as intracanal medicament in the study as internal resorption mainly occurs due to osteoclastic differentiation.

Mohammadi Z & Dummer suggested that $Ca(OH)_2$ should be combined with a liquid vehicle because the delivery of dry $Ca(OH)_2$ powder alone is difficult, and fluid is required for the release of hydroxyl ions.[88] Thus either water based vehicle or oil based vehicle can be used. Sterile water or saline are the most commonly used carriers. According to Nandini S et al, aqueous solutions promote rapid ion liberation and should be used in clinical situations. Oily vehicles leave residue on canal walls.[43]

However, Lambrianidis et al. (1999) revealed that the calcium hydroxide content does not influence the removal efficiency from the root canal wall.[18] Water base preparation has been preferred in the study.

Hasselgren et al. studied dissolution of necrotic porcine muscle tissue using a paste of $Ca(OH)_2$ powder and water. The combination was capable of dissolving tissues after 12 days of exposure. Furthermore, they reported an enhancement of the tissue-dissolving capability of NaOCl when the tissue was pretreated with $Ca(OH)_2$ for 30 min, 24 h and 7 days.[11] In another study, Metzler & Montgomery (1989) demonstrated the effect of long-term (7 days) pretreatment with Pulpdent paste (Watertown, MA, USA), a non-setting $Ca(OH)_2$ paste, followed by sodium hypochlorite irrigation. There was better cleaning of canal isthmus in mandibular molars than the use of hand instrumentation alone. [35] Thus calcium hydroxide has been used for a week in the present study.

In the control group, calcium hydroxide was not removed. This was to have a benchmark sample against which others were compared.

Scanning electron microscopic examination in a study done by Calt & Serper revealed that $Ca(OH)_2$ was not completely removed from the root canal surfaces, and root canal sealers did not penetrate into the dentinal tubules when only 5%NaOCI was used. Use of 17%EDTA followed by 5%NaOCI irrigation resulted in complete removal of $Ca(OH)_2$ and penetration of root canal sealers into the dentinal tubules.[17] Margelos et al observed that canal systems treated with calcium hydroxide as interappointment dressing and irrigated with 2.25% NaOC1 solution before obturation, showed handling problems. These problems were not found when root canals were treated with files, 15% EDTA and 2.25% NaOC1 solution.[18] Rodig et al also concluded that NaOCl alone has limited effectiveness in removal of calcium hydroxide.[48] Therefore in present study, NaOCl and EDTA with intermittent use of saline were used as irrigating solution for removal of calcium hydroxide

Considering that the effectiveness of irrigation could depend on both the mechanical flushing action and the chemical ability to dissolve tissue (Calt & Serper 1999,[17] Lee et al. 2004[89]), similar amount of the irrigant solution was used for all the groups in the present study.

Stereomicroscope is the most commonly employed and economical method for evaluation of calcium hydroxide. In previous studies, the amount of $Ca(OH)_2$ in the canal was calculated by measuring the surface area of the residues on the canal walls in terms of mm^2 (Lambrianidis et al,[18] Kenee et al.,[86] Balvedi et al.[46]), by using a scoring method (van der Sluis et al.,[73] Rodig et al.[48]), by using a scanning electron microscopy (Salgado et al.,[90] Kuga et al.[91]) or a volumetric analysis by spiral CT (Nandini et al[43].). In present study, the teeth were sectioned longitudinally, the canals were cleaned of all extraneous debris remnants and the two halves reapproximated. After each removal technique, the roots were disassembled and evaluated under Stereomicroscope which were analysed with digital image analyser to measure the percentage covered with residual materials. This is similar to the method employed by Tasdemir et al.[87] Stereomicroscope has been used as it is the most commonly employed technique and it is readily available. Digital analysis has been preferred over scoring system as they exhibit lesser variation as compared to scoring system where there are chances of variation in interindividual agreement and intraindividual reproducibilty.

To reduce the variability, all the samples were prepared and investigated by one operator using the standard technique.

In the present study, the difference obtained across five groups was statistically highly significant with p-value < 0.0001. Manual Dynamic Agitation, Canal Brush and EndoVac were found to be superior when compared to conventional syringe in removal of calcium hydroxide from internal resorption cavity. EndoVac was found to be the most potent of all techniques followed by Canal Brush and then Manual Dynamic Agitation. No technique could remove calcium hydroxide completely from internal resorption defect.

Both irrigant volume and fluid flow dynamics are important factors that affect canal debridement. The flushing action created by syringe irrigation is relatively weak and it depends not only on the anatomy of the root canal system but also on the depth of placement and the diameter of the needle.[20] Walters et al concluded that increase in the volume of irrigant does not significantly improve its flushing action and its efficacy to remove debris.[92] Boutsiokis et al found that traditional needle irrigation delivers solutions no further than 1 mm past the tip of the needle and is relatively ineffective in cleaning the apical third of canal walls.[93] This could be the reason for more amount of calcium hydroxide remaining in this group.

The results of the present study are in accordance with the study done by Kirar et al where they compared the efficacy of Manual Dynamic Agitation with conventional syringe in removing calcium hydroxide from root canal system. Manual Dynamic Agitation was found to be better than conventional syringe.[57] Manual Dynamic Agitation technique may be useful in breaking the air bubble located at the apical 0 –2 mm of the canal with repeated gutta-percha insertion. This creates enough flow of irrigant to remove debris from the canal system. This may be the reason for better removal as compared to conventional syringe. However there is no direct mechanical contact with calcium hydroxide in the deep confines of internal resorption defect which might be the reason for its less effectiveness than Canal Brush and EndoVac.

Canal Brush activation improved the removal of debris from simulated canal extensions and irregularities in the apical portions of curved root canals (Weise et al.).[24] In another study, irrigation by agitation with the Sonicare/Canal Brush improved root canal debridement in the apical thirds of the root canal (Salman et al) when compared to conventional syringe.[94] The bristles touching the canal walls might mechanically dislodge calcium hydroxide leftovers, thus providing a better performance than conventional syringe and Manual Dynamic Agitation.

Yeucel et al reported that the EndoVac system is superior to conventional irrigation needles in removing $Ca(OH)_2$ medicament from the root canal system. It was found that EndoVac delivers significantly more volume of irrigant than volume delivered with syringe irrigation over the same amount of time. While the cannulas are in the canal, a constant flow of fresh irrigant is being delivered by negative pressure to working length.[50] Also negative pressure technique employed in the irrigation system comes to an advantage as it helps in breaking the apical vapor lock.

Contrary to this, Capar et al did a study where the longitudinal grooves were created to simulate uninstrumented canal extensions in the apical half. The study revealed no difference in removal efficiency of EndoVac vs conventional syringe.[95]

Kungwani M et al (2014) compared cleaning efficacy of EndoVac with conventional irrigation needles in debris removal from root canal. No statistically significant difference was found at 3 mm level between the groups. Teeth in EndoVac group had significantly less debris at 1 mm level. EndoVac was found to be better in removing debris from the apical thirds of root canals.[52] In the present study, effectiveness of EndoVac was found to be significantly better than conventional syringe, Manual Dynamic Agitation and Canal Brush.

Thus the results obtained from our study warrant rejection of the null hypothesis that there is no difference between efficacy of conventional syringe, Manual Dynamic Agitation, Canal Brush and EndoVac in removal of $Ca(OH)_2$from internal resorption cavity.

Overall, EndoVac system can be considered as a good system for removal of $Ca(OH)_2$when used as an intacanal medicament even in canal irregularities like internal resorption. Also Manual Dynamic Agitation is a better economical chairside technique than conventional syringe in removal of medicaments from irregularities as well.

LIMITATIONS

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1. The extracted teeth show degrees of variation though all care was taken to maintain them by proper and recommended storage.

2. Since this was an in vitro study, the exact simulation of the oral conditions was not possible. Therefore, the results cannot be directly extrapolated to the clinical situation.

3. Making standardized grooves with bur do not represent exactly the irregular anatomy of internal resorption cavity in vivo. Thus, the use of the groove model might result in an overestimation of the removal efficacy of irrigation systems.

4. Disc along with chisel and mallet were used for sectioning teeth with minimal loss of tooth structure but tooth loss is inevitable in sectioning and thus proper approximation is not always achieved.

SUMMARY AND CONCLUSION

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The fundamental of endodontic practice is conservation and preservation of teeth. The infected root canal system becomes a privileged sanctuary for microorganisms, their by-products and degradation products of pulpal tissue. Hence the goal of root canal treatment is to eradicate micro-organisms from the pulp space and the filling of the root canal system to prevent re-infection.

The aim of the present study was to evaluate the efficacy of conventional syringe, Manual Dynamic Agitation, Canal Brush and EndoVac in removing calcium hydroxide from an experimental internal resorption cavity.

100 Human maxillary single rooted extracted teeth fulfilling the selection criteria were selected for the study. All the samples were decoronated and

biomechanical preparation done. Then the samples were sectioned buccolingually using diamond disc, chisel and mallet. The internal resorption cavity was created followed by reapproximation of the two sections. The canal and resorption defect was then filled with $Ca(OH)_2$.

Depending upon the technique of removal of calcium hydroxide from internal resorption cavity, the samples were randomly divided into 5 groups as follows:-

GROUP	DISTRIBUTION	NO OF SAMPLES
1	Control group (Internal resorption defect filled with $Ca(OH)_2$ but not removed)	20
2	Removal of $Ca(OH)_2$ using conventional syringe	20
3	Removal of $Ca(OH)_2$ using Manual Dynamic Agitation	20
4	Removal of $Ca(OH)_2$ using Canal Brush	20
5	Removal of $Ca(OH)_2$ using EndoVac	20

The two sections were separated and evaluated under Stereomicroscope (Image Analysis System, model no.-MVIG2005) for calculating the amount of remaining $Ca(OH)_2$ after removal and statistically compared.

The results obtained indicated that there was highly significant difference in removal of calcium hydroxide between control group and all other groups ($P<0.0001$). The inter group comparison revealed that maximum amount of $Ca(OH)_2$ was detected after irrigation with conventional syringe(Group II), followed by Manual Dynamic Agitation (Group III), Canal Brush (Group IV) and EndoVac (Group V).

Within the limitations of the study, following conclusions can be drawn-

1. All irrigation systems used here left some remaining $Ca(OH)_2$ within the internal resorption defect and none of the technique is proven to completely remove $Ca(OH)_2$ from the defect.

2. The amount of $Ca(OH)_2$ remaining within the internal resorption defect was significantly lower in all the groups when compared with control group.

3. Least amount of $Ca(OH)_2$ was found in Group V (EndoVac), followed by Group IV (Canal Brush)and Group III (Manual Dynamic Agitation), whereas maximum amount was detected in Group II (conventional syringe). Overall, EndoVac performed better in removing $Ca(OH)_2$ from internal resorption defect than Canal Brush, Manual Dynamic Agitation and conventional syringe.

4. Manual Dynamic Agitation found to be better than conventional syringe and thus it can be a more better and economical technique than conventional syringe.

Taking into consideration the finding of the study, it can be concluded that under experimental conditions, EndoVac was significantly better than Canal Brush, Manual Dynamic Agitation and conventional syringe.

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TABLES AND GRAPHS

TABLE NO. 1

Descriptive statistics for percentage of calcium hydroxide remaining in the internal resorption cavity according to study groups

Groups	N	Mean (%)	SD (%)	Median (%)	Min (%)	Max (%)
GROUP-I (CONTROL)	20	99.87	0.32	100.00	98.70	100.00
GROUP-II(CONVENTIONAL SYRINGE)	20	83.58	9.38	83.85	64.80	95.90
GROUP-III (MANUAL DYNAMIC AGITATION)	20	45.54	9.64	47.63	26.10	60.60
GROUP-IV (CANAL BRUSH)	20	24.25	6.80	23.68	14.75	44.40
GROUP-V (ENDOVAC)	20	6.21	5.77	3.68	0.00	19.75

TABLE NO. 2

Comparison of percentage of calcium hydroxide remaining in the internal resorption cavity according to study groups

Groups (n)	Mean (%)	SD (%)	Median (%)	Min (%)	Max (%)	P-value
GROUP-I (CONTROL) (20)	99.87	0.32	100.00	98.70	100.00	< 0.0001 (HS)
GROUP-II (CONVENTIONAL SYRINGE) (20)	83.58	9.38	83.85	64.80	95.90	
GROUP-III (MANUAL DYNAMIC AGITATION) (20)	45.54	9.64	47.63	26.10	60.60	
GROUP-IV (CANAL BRUSH) (20)	24.25	6.80	23.68	14.75	44.40	
GROUP-V (ENDOVAC) (20)	6.21	5.77	3.68	0.00	19.75	

Calculated using Kruskal-Wallis test; HS: Highly Significant

TABLE NO. 3

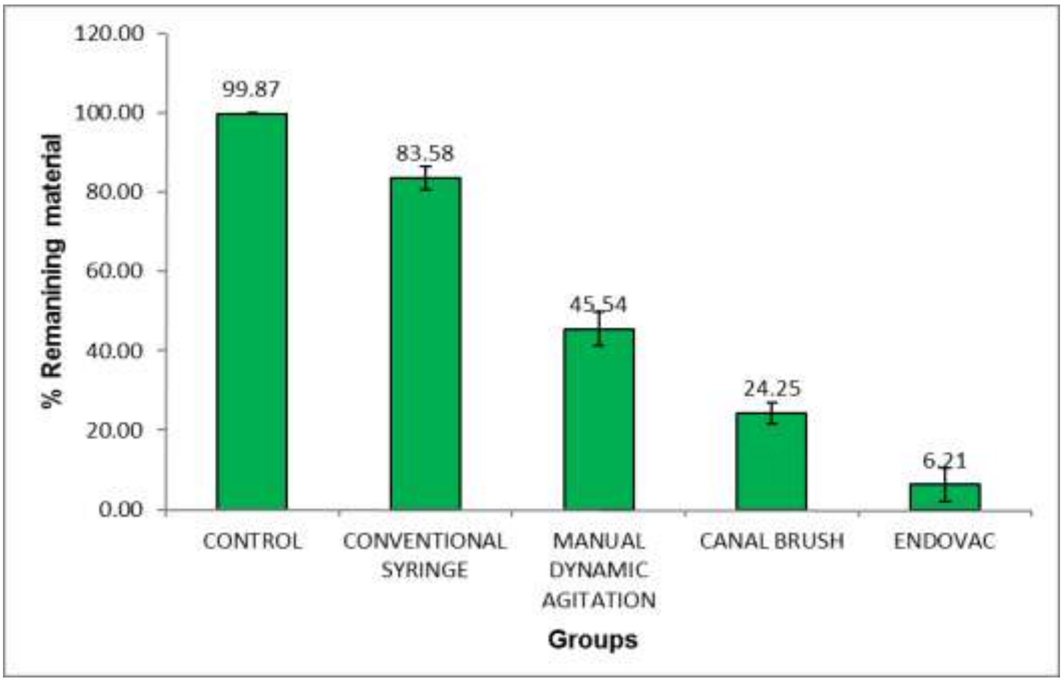
Pair-wise comparison of percentage of calcium hydroxide remaining in the internal resorption cavity according to study groups

Paired Groups	P-value
I - II	< 0.0001 (HS)
I - III	< 0.0001 (HS)
I - IV	< 0.0001(HS)
I - V	< 0.0001 (HS)
II - III	< 0.0001 (HS)
II - IV	< 0.0001 (HS)
II - V	< 0.0001 (HS)
III - IV	< 0.0001 (HS)
III - V	< 0.0001 (HS)
IV - V	< 0.0001 (HS)

Calculated using Wilcoxon rank sum test; HS: Highly Significant

GRAPH

Column chart showing percentage of calcium hydroxide remaining in the internal resorption cavity according to study groups



ANNEXURE

MASTER CHART

GROUP-I (CONTROL)			GROUP-II (CONVENTIONAL SYRINGE)		
Sr No.	Sample No	%Remaining material	Sr No.	Sample No	%Remaining material
1	1.1	100	1	1.1	76.8
	1.2	100		1.2	75.8
2	2.1	99.8	2	2.1	65.8
	2.2	99.9		2.2	63.8
3	3.1	100	3	3.1	94
	3.2	100		3.2	93.8
4	4.1	100	4	4.1	87.6
	4.2	100		4.2	84.8
5	5.1	100	5	5.1	93.8
	5.2	100		5.2	93
6	6.1	99.6	6	6.1	87.8
	6.2	99.7		6.2	87.6
7	7.1	99	7	7.1	95.4
	7.2	99.7		7.2	96.4
8	8.1	100	8	8.1	78.5
	8.2	100		8.2	79.5
9	9.1	100	9	9.1	65.3
	9.2	100		9.2	69.7
10	10.1	100	10	10.1	76.8
	10.2	100		10.2	79.6
11	11.1	100	11	11.1	92.7
	11.2	99.9		11.2	91.1
12	12.1	100	12	12.1	85.6
	12.2	100		12.2	82.6
13	13.1	99.4	13	13.1	92.7
	13.2	98		13.2	93.6
14	14.1	100	14	14.1	80.7
	14.2	100		14.2	82.9
15	15.1	100	15	15.1	74.7
	15.2	100		15.2	78.4
16	16.1	100	16	16.1	94
	16.2	100		16.2	92
17	17.1	100	17	17.1	94.7
	17.2	99.9		17.2	93.8
18	18.1	100	18	18.1	79.8
	18.2	100		18.2	77
19	19.1	100	19	19.1	69.9
	19.2	100		19.2	73.8
20	20.1	100	20	20.1	87.5
	20.2	100		20.2	79.7

GROUP-III (MANUAL DYNAMIC AGITATION)			GROUP-IV (CANAL BRUSH)		
Sr No.	Sample No	%Remaining material	Sr No.	Sample No	%Remaining material
1	1.1	56.9	1	1.1	22.3
	1.2	59		1.2	20.4
2	2.1	62.2	2	2.1	16.3
	2.2	59		2.2	17.9
3	3.1	48.6	3	3.1	25
	3.2	49.8		3.2	12
4	4.1	43.8	4	4.1	18.3
	4.2	45.8		4.2	14.3
5	5.1	52.7	5	5.1	25.5
	5.2	53.9		5.2	28
6	6.1	48.9	6	6.1	27.4
	6.2	46.4		6.2	29
7	7.1	53.7	7	7.1	23.8
	7.2	58.4		7.2	22.6
8	8.1	52.9	8	8.1	30.2
	8.2	49.7		8.2	28.6
9	9.1	55.6	9	9.1	26.3
	9.2	45.2		9.2	28
10	10.1	28.5	10	10.1	10.5
	10.2	29.7		10.2	19
11	11.1	39.4	11	11.1	26.4
	11.2	37.8		11.2	29.6
12	12.1	43.6	12	12.1	18.7
	12.2	42.9		12.2	16.9
13	13.1	38.6	13	13.1	29.7
	13.2	35.8		13.2	25.9
14	14.1	48.7	14	14.1	20
	14.2	47.4		14.2	22.9
15	15.1	57.8	15	15.1	45
	15.2	52.9		15.2	43.8
16	16.1	39.6	16	16.1	21.8
	16.2	28.4		16.2	19.7
17	17.1	22.7	17	17.1	21.9
	17.2	29.5		17.2	18.8
18	18.1	37.9	18	18.1	23.7
	18.2	30.7		18.2	24.6
19	19.1	46.9	19	19.1	29.6
	19.2	48.3		19.2	34.7
20	20.1	48.9	20	20.1	27
	20.2	42.9		20.2	24

GROUP-V (ENDOVAC)		
Sr No.	Sample No	%Remaining material
1	1.1	5.2
	1.2	2.3
2	2.1	20.2
	2.2	11
3	3.1	2
	3.2	5.3
4	4.1	1.8
	4.2	5
5	5.1	20
	5.2	5.8
6	6.1	10.2
	6.2	10.6
7	7.1	0
	7.2	0
8	8.1	1.1
	8.2	1.1
9	9.1	3.1
	9.2	4
10	10.1	2.2
	10.2	4.2
11	11.1	6
	11.2	5
12	12.1	2
	12.2	5.4
13	13.1	2.4
	13.2	2.1
14	14.1	15
	14.2	20.8
15	15.1	22
	15.2	17.5
16	16.1	4.3
	16.2	2.4
17	17.1	3.6
	17.2	3.3
18	18.1	2.7
	18.2	2.9
19	19.1	3.6
	19.2	4
20	20.1	5.3
	20.2	3