

Original Research**To Compare the Penetration Depth of Sodium Hypochlorite into the Dentinal Tubules in apical third area after Conventional Syringe Irrigation, Ultrasonic Irrigation and Laser Activated Irrigation Techniques – An Invitro Study****Kalpna Pawar¹, Riya Kapadia², Sadashiv Daokar³, Pawan Raktade⁴, Ajay Jadhav⁵, Neha Chavan⁶**¹ Professor, Department of Conservative dentistry and Endodontics, C.S.M.S.S Dental college and Hospital, Aurangabad, Maharashtra, India² Postgraduate student, Department of Conservative dentistry and Endodontics, C.S.M.S.S Dental college and Hospital, Aurangabad, Maharashtra, India³ Professor and H.O.D, Department of Conservative dentistry and Endodontics, C.S.M.S.S Dental college and Hospital, Aurangabad, Maharashtra, India⁴ Lecturer, Department of Conservative dentistry and Endodontics, C.S.M.S.S Dental college and Hospital, Aurangabad, Maharashtra, India^{5,6} Postgraduate student, Department of Conservative dentistry and Endodontics, C.S.M.S.S Dental college and Hospital, Aurangabad, Maharashtra, India

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ABSTRACT

Aim: The purpose of this study was to evaluate the efficacy of three different irrigation delivery techniques; conventional syringe irrigation, ultrasonic irrigation and laser activated irrigation with 5% of sodium hypochlorite in apical third area.

Methods: A comparative study regarding the penetration depth of sodium hypochlorite (NaOCl) solution in dentinal tubules using three methods, (1) conventional irrigation (CI), (2) ultrasonic irrigation (3) diode laser activated irrigation (LAI), conducted on 60 extracted mandibular premolar teeth with a single root canal. After decoronation with a diamond disc and working length determination, the canals were prepared upto 30.06 and the apical third were sealed with cyanoacrylate adhesive. Teeth were stained with crystal violet and then the samples were distributed into three experimental groups. Depth of the bleached zone was evaluated by stereomicroscope. Data were analysed by ANOVA test and Post- hoc Tukey's test using IBM SPSS-20 software.

Result: Statistical analysis indicated that ultrasonic irrigation had the highest penetration depth of sodium hypochlorite in the apical third area followed by diode laser activated irrigation and conventional syringe irrigation.

Conclusion: Agitation with activation of the irrigant helps in its deeper penetration into the dentinal tubules.

Introduction

Complete cleaning and shaping of the root canal system is one of the most important steps of endodontic treatment, which is performed by removal of the necrotic pulp tissue, inorganic and organic debris, micro-organisms and their by-products with the use of instruments and intracanal irrigant.¹

Instrumentation of the root canal reduces the microbial content to a great extent. However, the root canal anatomy i.e., lateral or accessory canals, apical deltas, isthmus, ramification and dentinal tubules are barely cleanable by bio-mechanical canal preparation and provides areas in which bacteria can persist. Bacterial penetration to a depth of 300 µm into the dentinal tubules has been reported;

penetration depths >500 µm and high prevalence in cases of persistent apical periodontitis have been reported for *Enterococcus faecalis*.² Hence the penetration depth of root canal irrigant into the dentinal tubules is a factor that improves the disinfection of the root canal system, contributing to better prognosis of root canal treatment.²

Sodium hypochlorite (NaOCl) is the main endodontic irrigant used, due to its antibacterial properties and its ability to dissolve organic tissues.³ Its effectiveness has been shown to depend on its concentration, temperature, pH solution and storage conditions.⁴ The greatest penetration of NaOCl into dentinal tubules has been reported as being 300µm with a

concentration of 5% for 20 mins at 45 °C.² However, a major drawback of NaOCl is its high surface tension, which limits the penetration into canal irregularities and the depth of dentinal tubules.⁵

Irrigation systems helps to increase the penetration depth of irrigants in dentinal tubules, while encountering minimal apical extrusion of irrigants, eliminating cytotoxic effects on periapical tissues and exhibiting superior disinfection effects.⁶ Root canal irrigation systems can be divided into two main groups, including hand agitation techniques and agitation with activation techniques using devices.

Conventional syringe irrigation consists of irrigation with positive forces, commonly by the use of syringes and side-vented needles but it does not guarantee flow of the irrigant to all areas of the root canal system. In fact, negligent irrigation may leave large areas of the canal(s) un-irrigated.

One of the ways in enhancing root canal disinfection is NaOCl activation, which initiates dynamics and fluxes within the irrigant, promoting its penetration through all aspects of the root canal system.⁷ One of the widely used techniques for activation of NaOCl is the Ultrasonic Irrigation system, where ultrasonic action produces agitating flows (through acoustic microstreaming) capable of increasing NaOCl penetration into tubules.⁸ Several studies have shown that final irrigation with NaOCl solution in association with ultrasonic irrigation removes more debris, bacteria⁹ and pulp tissue¹⁰ when compared with conventional syringe irrigation.

Lasers too have been used for activation of the irrigant as they have photo biologic effects including photoacoustic, photochemical and photothermal effects.¹¹ Laser Activated Irrigation (LAI) aims at increasing irrigant activation by photoacoustic technique; i.e., effective absorption of laser light by sodium hypochlorite leading to the formation of large oval vapor bubbles which expands and implodes subsequently to the use of ablative lasers in an aqueous environment.

Hence, this study aims to evaluate the extent of penetration of sodium hypochlorite into dentinal tubules by using conventional syringe irrigation, ultrasonic irrigation system, and Laser Activated Irrigation. Thus, determining the most effective irrigation system for endodontic treatments among the three.

Method and material:

Sample preparation

Sixty extracted human permanent mandibular premolars with fully formed apex with single root having single canal were collected from Oral and Maxillofacial surgery department of our college. Teeth with presence of caries, previous restoration, previously endodontic treatment, pre-existing fracture or cracks, developmental anomalies or anatomical variation, external resorption, internal resorption and calcification were excluded from this study. The entire samples were marked to standardize the root length at 12 ± 1 mm and were decoronated using a straight hand piece and tooth sectioning disc at low speed under water spray.

The patency of the canal was determined by inserting size 10 K-hand file. After seeing the tip of file in the apical foramen, 1 mm was reduced from the length of file and was confirmed with the help of digital radiographs. The enlargement of the apical foremen and the canal taper was done with a Neoendo flex files upto 30.06. Each instrument was introduced to working length starting with small instruments and followed by files of increasing diameter and taper. Between each instrument changeover, the canal was irrigated with 1 ml of 5% NaOCl for 1 min followed by normal saline. The canals were then irrigated with 1 ml of 17% EDTA. The root canals were finally irrigated with 5 ml of normal saline to remove chemical residues, and then were dried internally with absorbent paper points.

Sample staining

All the tooth samples were kept in crystal violet dye and were maintained at room temperature for 72 hrs.; crystal violet dye was renewed every 12 hrs. Then the tooth samples were washed with distilled water and apical third of each tooth were coated with a layer of cyanoacrylate adhesive. After staining, the teeth were distributed by simple random sampling into three groups (n=20) according to the irrigation protocol.

GROUP 1 (activation by conventional syringe irrigation technique)

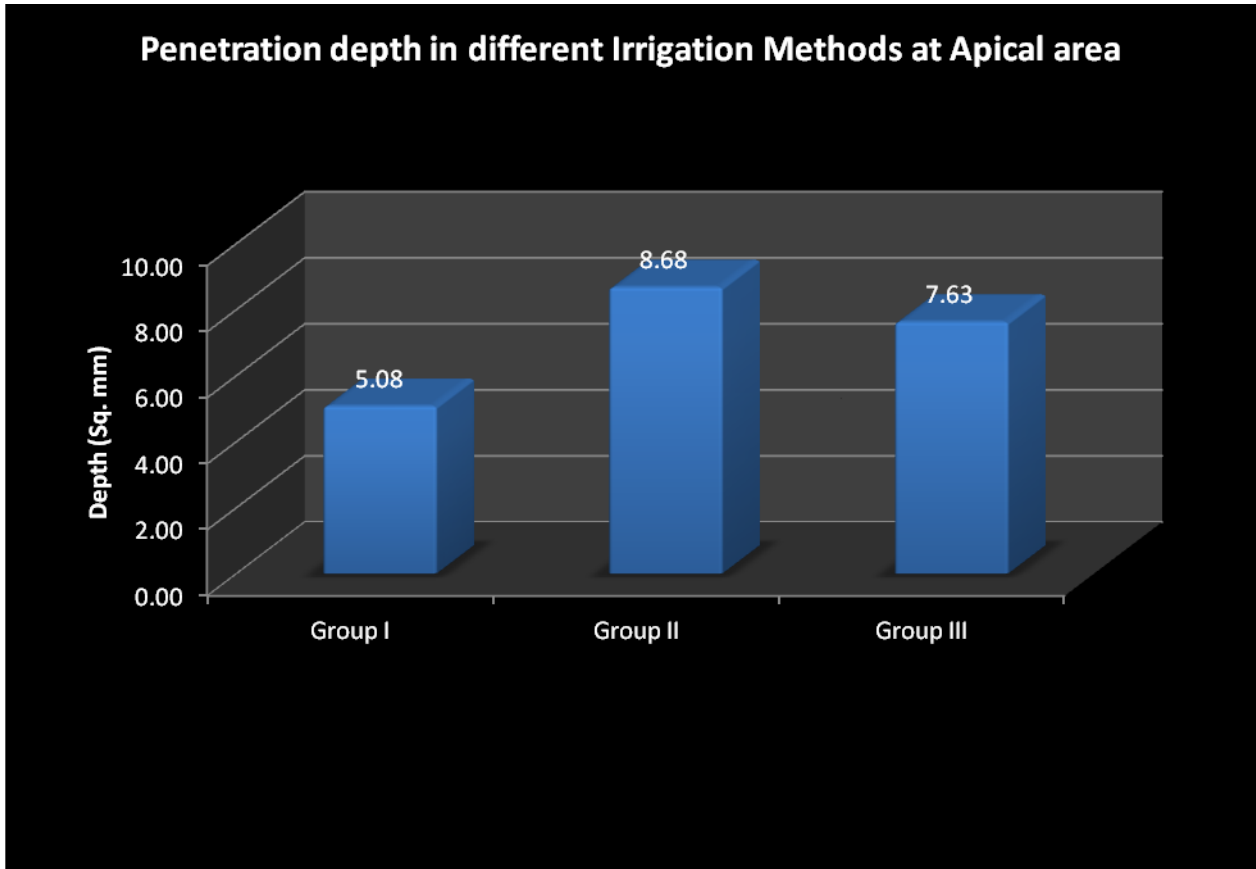
The canals were irrigated with 5% NaOCl and the irrigant was agitated using a syringe with a 30-gauge side-vented needle placed 1 mm from the working length and passively into the canal. The tip was moved in up and down motion in

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Group I	20	5.08	1.82	0.41	3.33	8.47
Group II	20	8.68	0.52	0.12	7.15	9.27
Group III	20	7.63	0.43	0.10	6.86	8.45

Table 1 Mean penetration depth of sodium hypochlorite at apical third in sq.mm

Position	Group	Group	Mean Difference	Std. Error	Sig.	Result
Apical	Group I	Group II	-3.59950*	.35463	.000	Significant
		Group III	-2.55000*	.35463	.000	Significant
	Group II	Group III	1.04950*	.35463	.004	Significant

Table 2 Mean difference between groups



Graph 1 Mean penetration depth in groups

the canal for 30 seconds. Then, NaOCl was left in the root canal for 30 seconds without any movement. Hence, the total time of NaOCl into the canal was 60 seconds and total quantity used was 2ml. Final irrigation was accomplished by normal saline for 60 seconds.

GROUP 2 (activation by ultrasonic device)

The canals were irrigated with 5% NaOCl and the irrigant was activated by an ultrasonic device (Ultra X) using tip X Blue with a size of 0.20 mm and 2% taper which was placed 1mm short from the working length and passively into the canal. The tip was moved in up and down motion in the canal for 30 seconds with power set on high output mode. The tip oscillated and vibrated in frequency 45 KHz. Then, NaOCl was left in the root canal for 30 seconds without any movement. Hence, the total time of NaOCl into the canal

was 60 seconds and total quantity used was 2ml. Final irrigation was accomplished by normal saline for 60 seconds.

GROUP 3 (activation by diode laser device)

The canals were irrigated with of 5% NaOCl and the irrigant was activated by using diode laser (sirolaser, 970nm) with a fiberoptic tip of 200 μ m inserting apically 1mm short from the working length with power set at 2W at 25Hz frequency. A slow helical movement was applied to the tip and was moved in up and down motion in the canal for 10 seconds. This was followed by 10 seconds of rest period i.e., NaOCl was left in the canal for 10 seconds without any movement. This cycle was performed three times (3x10=30) i.e., 30seconds of activation and 30 seconds of rest period. Hence, the total time of NaOCl into the canal was 60

seconds and total quantity used was 2ml. Final irrigation was accomplished by normal saline for 60 seconds.

After irrigation, all the samples were separated into two equal halves longitudinally by tooth sectioning disc. One half was randomly selected and the bleached area was evaluated under stereomicroscope in 4x magnification. Using photoshop software the tooth was divided into three equal parts and the bleached areas at the apical thirds were calculated. (fig. 1,2,3)

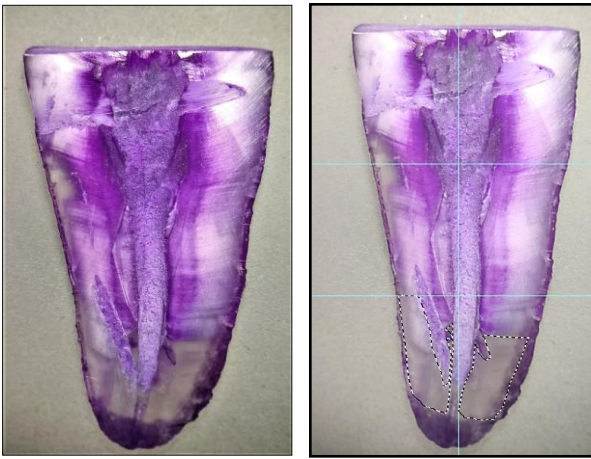


Fig. 1 Bleached area seen after agitation by Conventional Syringe Irrigation

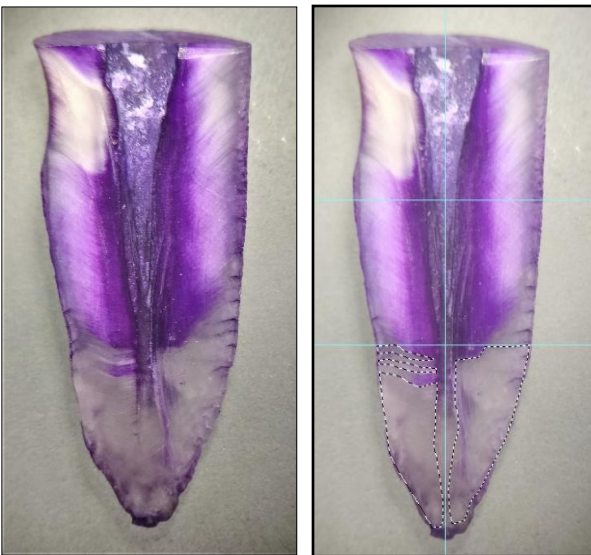


Fig. 2 Bleached area seen after activation by Ultrasonic device

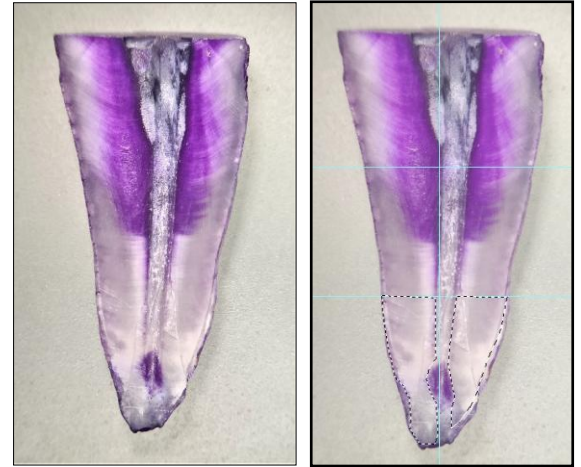


Fig. 3 Bleached area seen after activation by Diode laser device

Result:

All the values obtained from the study were tabulated and subjected to the statistical analysis using ANOVA test and Post- hoc Tukey's test using IBM SPSS-20 software, at the significance level of 0.05 (**$P \leq 0.05 = \text{Significant}$**).

The mean penetration depth for the various groups in apical third are, Group I (5.08 ± 1.82 SD), Group II (8.68 ± 0.52 SD) and Group III (7.63 ± 0.43 SD) (Table 1). Statistical analysis indicated that Group II had the highest penetration depth of sodium hypochlorite, which was significantly different from Group I and Group III (Graph 1). For Group I, mean difference of penetration depth was statistically significant with group II (-3.59) with p value (**$p=0.00$**) and with Group III (-2.55) with p value (**$p=0.00$**). For Group II, mean difference of penetration depth was statistically significant with group III (1.04) with p value (**$p=0.00$**) (Table 2)

Discussion:

Apical third of root canals have anatomical complexities like lateral canals, apical deltas, fins, webs, and transverse anastomoses, that harbours intraradicular biofilm. Current rotary and hand instrumentation lies in the fact that they cannot adapt to this anatomical complexity of a root canal system. Thus, it becomes important for intracanal irrigants

to be delivered to where rotary instruments are unable to perform their function. So, the penetration depth of the irrigant in the present study was evaluated in the apical third area. Study was conducted on human extracted teeth in an invitro condition as the extent and measuring the penetration depth of irrigant in dentin was not possible in vivo due to practical and moral limitations. Single rooted mandibular premolars were selected rather than multirooted teeth to attain standardization in canal anatomy. To standardize the root length all the teeth were marked at 12 ± 1 mm and coronal portion was sectioned using tooth sectioning disc. All teeth were subjected to working length determination by passing the 10k file into the root canal until visible at the apical foremen and adjusting the length 1mm short of apex, considering the findings of study conducted by Ricucci (1998)¹² who stated that location of apical foramen related to root canal most frequently ends short of apex, often by several millimeters (0.5 – 1mm). Sixty teeth were instrumented with NiTi neoendo flex files. The apical preparation was kept constant (ISO 30 and taper of 6%) in all the samples in order to attain standardization, this was based on the study by Khademi et al.¹³ The canals were irrigated using 5% sodium hypochlorite and 17% EDTA for smear layer removal. A solution of EDTA mixed with NaOCl retained calcium binding capacity of EDTA, but showed a rapid decrease in the amount of chlorine in NaOCl hence significantly reducing the ability of NaOCl to degrade tissue. So normal saline was used between each irrigating solution in order to prevent an acid/base reaction, between sodium hypochlorite and EDTA, for a more efficient action of the chemicals on the tissues. This was according to a study by Rossi-Fedele et al.¹⁴ Hypochlorous acid in sodium hypochlorite acts as strong oxidizing agent. Penetration of sodium hypochlorite solution using dye has been used as an index for evaluating penetration because of its oxidation ability (Zou et al. 2010).¹⁵ The reason for selecting crystal violet in the current study was better observation under stereomicroscope. It whitens the purple color of crystal violet and reveals the clear natural color of dentin. To simulate the clinical situation, an in vitro closed-end canal design was used that closely replicates the in vivo scenario in which the apical foramen is enclosed by the periodontal tissues.^{16,17} The apical third of all the tooth sample were coated with a layer of cyanoacrylate adhesive. This design maintains the irrigant within the confines of the root canal system and forces the irrigants to exit the canal coronally rather than apically or laterally.¹⁸

In the present study, the penetration depth of NaOCl into the dentinal tubules due to ultrasonic activation irrigation was more significant than laser activation irrigation and conventional syringe irrigation in apical third area of the teeth. Study in the agreement with our result was of **Yang SE, Kim YM**.¹⁹ in which anti-bacterial efficacy was more with passive ultrasonic irrigation than 980 nm-GaAlAs laser application in two root types. Another study in our agreement was of **Akyuz Ekim**²⁰ in which he evaluated the efficiency of different irrigation activation techniques on smear layer removal. The activation systems used were conventional syringe irrigation (CSI), passive ultrasonic irrigation (PUI, Group 3), EndoVac apical negative pressure (ANP, Group 4), diode laser (Group 5), Nd:YAG laser (Group 6), Er:YAG laser (Group 7), and Er:YAG laser using with photon-induced photoacoustic streaming (PIPSTM, Group 8). All experimental irrigation techniques except ANP and diode laser removed smear layer more effectively at the coronal and middle levels compared to the apical level ($P < 0.05$).

The mechanism behind ultrasonic is mainly cavitation and acoustic streaming. The concept of acoustic streaming was described as the rapid movement of particles of fluid in a vortex-like motion around a vibrating object. The fluid is transported from the apical to the coronal end, at a rate of a few centimetres per second, resulting in hydrodynamic shear stresses around the file which helps in removal of the smear layer or the biofilm present. While in laser activated irrigation, rapid fluid motion caused due to transfer of pulse energy to the irrigant and resulting in expanding and imploding of vapor bubbles. The reduced penetration of NaOCl in diode laser activated irrigation in our study may be due to the end firing tip of the laser, which resulted in heat generation causing the dentinal tubules to melt and fuse in the apical area. Hence, reduced penetration of the irrigant in the partially obliterated tubules. Ultrasonic irrigation and laser activated irrigation showed better results than conventional syringe irrigation. In conventional syringe irrigation, the irrigant has only a limited effect beyond the tip of the needle because of the dead-water zone or sometimes air bubbles in the apical root canal, which prevents penetration of the solution.

Conclusion:

A statistical difference between the penetration depth of sodium hypochlorite into dentinal tubules in apical third area was seen after using conventional syringe irrigation, ultrasonic irrigation and laser activated irrigation. Maximum penetration of NaOCl into dentinal tubules was seen by ultrasonic irrigation followed by laser activated irrigation and conventional syringe irrigation respectively. Conventional syringe irrigation showed least penetration of NaOCl into the dentinal tubules.

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