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Effect of Apical Preparation Size and Taper on Irrigant Penetration in Apical Third of Root Canal using Two Different Endodontic Needles: An *In Vivo* Study

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Abstract

Introduction: Many *in vitro* studies have debated over the appropriate apical preparation size and taper for the irrigant to reach the apical third of root canals; however little is known about irrigant penetration *in vivo*.

Aim: The purpose of this *in vivo* study was to determine the effect of apical preparation size and taper using two different needles on the irrigant penetration into the apical part of root canals.

Materials and Methods: A 120 human mandibular teeth indicated for root canal treatment was selected for the study. The study was done in two phases. The first phase aimed to determine the smaller apical size that will allow irrigant penetration to working length. Disto buccal canal of with mandibular 1st molar was selected for study and was sequentially instrumented to 30/0.04 and 35/0.04. All patients were randomly divided into two groups for irrigation: Group A (n=30) 30G flat open ended needle and Group B (n=30) 30G side vented needle. The second phase of the study aimed to determine the taper that will allow irrigant penetration to working length. Teeth were instrumented to 30/0.04 and 30/0.06 and for irrigation patients were randomly divided into group A and B (n=30). Diatrizoate sodium contrast medium was used to measure irrigant penetration with digital radiograph. A blinded observer measured the distance between the working length and maximum irrigant penetration.

Results: In both groups A and B, increasing the preparation size of the DB canal from 30 to 35 increased irrigant penetration which was statistically insignificant (p>0.05). But irrigant penetration in 6% taper of DB canal was significantly better than 4% (p<0.001) for both the groups. Flat open ended needles performed significantly better than side vented needles in both phase I and II of the study (p<0.001).

Conclusion: Within the limitations of the study it can be concluded that an apical preparation size of 30 and 6% preparation taper in DB canal of mandibular molars allow adequate irrigation penetration in the apical third with flat open ended needles performing better than side vented needles.

Keywords: Flat ended needle; Irrigant penetration; Radiopaque dye; Side vented needle; Size; Taper

Introduction

Removal of vital and necrotic remnants of pulp tissues, microorganisms, and microbial toxins from the root canal system is essential for endodontic success [1]. The goals of endodontic instrumentation thus include thorough debridement and disinfection of the root canal system in addition to create a suitable shape for complete obturation.

Mechanical instrumentation alone is ineffective in completely removing residual bacteria and necrotic debris [2]. Even with the use of the nickel-titanium rotary instruments currently available, they act only on the central body of the canal, leaving canal fins, isthmi, and cul-de-sacs untouched after completion of the preparation [3,4]. Therefore, irrigation is an essential part of the root canal debridement because it allows for cleaning beyond what might be achieved by root canal instrumentation alone. The penetration of the irrigant and the flushing action created by irrigation are dependent not only on the anatomy of the root canal system, but also on the system of delivery,

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the depth of placement, and the volume and fluid properties of the irrigant [5-12]. There are varying theories with regard to the optimal size and shape of root canal preparations necessary to satisfy these goals. Salzgeber and Brilliant [13] reported that irrigant penetrated to the full depth of instrumentation in 79% of root canals when prepared to size #35 and flared with #2 Gates Glidden drill. Khademi et al. [14] also reported that apical instrumentation up to #30 file with 6% coronal taper is effective for the removal of debris and smear layer from the apical portion of root canals. All these *in vitro* studies have debated over the appropriate apical preparation size and taper for the irrigant to reach the apical third of root canals; however little is known about irrigant penetration *in vivo*. Conventional irrigation with syringes still remains widely accepted [15,16], and has also been advocated as an efficient method of irrigant delivery prior to passive ultrasonic activation [17]. Appropriate size and type of needle to allow irrigant penetration in apical third of root canal has always been a dilemma to the dentists. Thus, the aim of this study was to determine the effect of root canal size and taper using two different endodontic needle types on the irrigant penetration into the apical part of canals with the help of radiopaque dye.

Materials and Methods

The randomized clinical study was conducted in the department and the ethical clearance (Ref- 315/2012-13) was obtained from the institutional ethical committee. One hundred and twenty patients between age group 18-45 years with mandibular first molar indicated for root canal treatment and who signed informed consent were randomly selected for the study. Inclusion criteria were teeth with two separate and completely developed roots, enough crown structure for adequate isolation with rubber dam and disto-buccal (DB) canals with less than 20° curvature using Schneider's methods. Medically compromised, allergy to any component of formula and pregnant patients were excluded from the study. Patients were anesthetized with 1.8 ml 2% lignocaine with 1:100,000 epinephrine by inferior alveolar nerve block. After rubber dam isolation access cavity was prepared using Endo access bur (Dentsply Maillefer, Ballaigues, Switzerland) and canals were located under dental operating microscope. The coronal third was preflared using the Sx files of ProTaper rotary (Denstply Maillefer) instruments. Working length (WL) was estimated using a15 K-file and digital X-ray (Digora; Sopro imaging, France) using paralleling technique (RINN Endo Ray II Ring) which was confirmed using an electronic apex locator (J Morita Corp, Tokyo, Japan). The study was conducted in two phases. Phase I (60 patients) was aimed at determining the apical enlargement that would significantly increase the depth of irrigant penetration to working length. DB canals selected for study, were cleaned and shaped with hand files #25 followed by RaCe rotary files to size 25/0.04, 30/0.04 and 35/0.04 following manufacturer's instructions. These patients were randomly divided into two study groups for irrigation with 2 ml of 3% NaOCl during instrumentation. Group A (n=30) 30G flat open ended needle. Group B (n=30) 30G side vented needle.

Irrigation protocol

A standardized irrigation protocol was followed. A new sterile needle and syringe combination was used for each tooth. A stopper was placed on the needle to adjust the length 2 mm short of WL in flat open ended needles (group A) and 1 mm short in side vented needles (group B) or where the needle first binds to the canal. An aseptic technique was strictly adhered to at all times. After canal

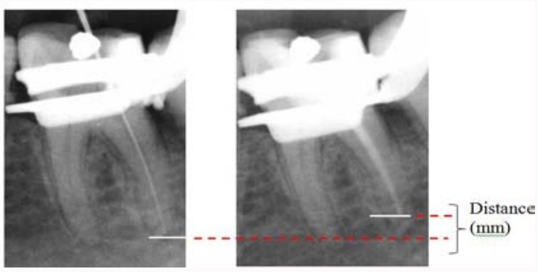


Figure 1: Differences between WL and urografin penetration after 30/0.04 preparation in group A using digora.

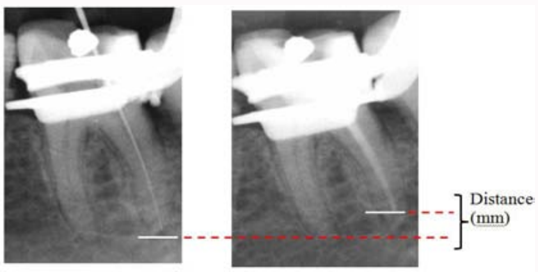


Figure 2: Differences between WL and urografin penetration after 30/0.06 preparation in group A using digora.

preparation to 30/0.04 the DB canal was dried using paper points and other canal orifices were blocked using cotton. For evaluation of irrigant penetration radiographically diatrizoate sodium (Urografin) was injected at the rate of 1 ml in 30 sec with an up-and-down motion using either flat ended or side vented needle depending on the group. A digital radiograph was obtained using paralleling technique. The dye was flushed out using saline. The root canal was then enlarged to 35/0.04 and another radiograph was taken with contrast media in both the groups as described earlier. Copious irrigation with saline was used to flush out the dye. Phase II (60 patients) of the study was aimed to determine the taper in the root canal that will allow increase in irrigant penetration depth. DB canal was sequentially instrumented to 30/0.04 and 30/0.06 and canals were irrigated using either flat ended or side vented needles (group A and B) as described earlier. Radiographs were taken with radiopaque dye inside the canal after both preparations. Radiographs were taken using same parameters to ensure minimum distortion between 2 images for the evaluation of penetration of irrigating solution. With the aid of digital X-ray, a blinded observer measured the distance between the WL and maximum irrigant penetration in mm (Figure 1 and 2). Differences between WL and irrigant penetration between 30/0.04 and 35/0.04 in phase I, and 30/0.04 and 30/0.06 in phase II using two different needles were calculated. The data obtained were analyzed by student 't' test using SPSS (Statistical Package for Social Sciences) software. The level of significance was set at $p<0.05$.

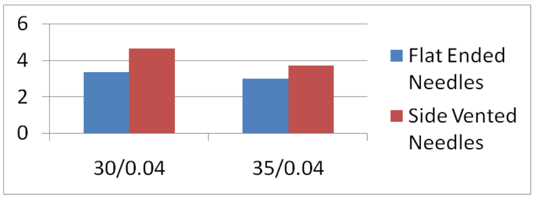
Results

The results of phase I of the study showed that when flat open ended needles (group A) and side vented needles (group B) were used the mean irrigant penetration with 30/0.04 and 35/0.04 was short of WL, with 35/0.04 showing slightly better results which was not statistically significant ($p>0.05$) (Table 1 and Graph 1). In phase II of the study, when flat open ended and side vented needles (group A and B) were used the mean irrigant penetration with 30/0.04 and 30/0.06 was short of WL. 30/0.06 preparation revealed statistically

Table 1: Comparison of irrigant penetration depth between 30 4% & 35 4% in flat ended and side vented needles (t-test).

Group	Size	Mean	StdDev	SE of Mean	Mean Difference	t	P-Value
Flat ended needles	30 4%	3.36	1.25	0.39	0.375	0.679	0.505*
	35 4%	2.99	1.22	0.39			
Side vented needles	30 4%	4.68	0.91	0.29	0.969	2.541	0.514*
	35 4%	3.71	0.79	0.25			

*denotes significant difference; Higher mean irrigant penetration depth was recorded in 35 4% compared to 30 4% but the difference between them was found to be statistically insignificant (P>0.05).

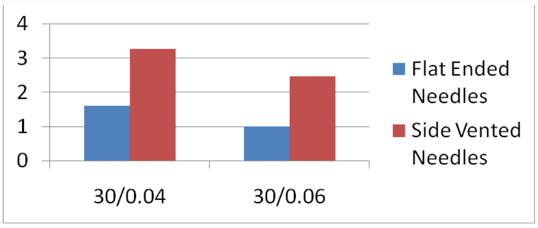


Graph 1:

Table 2: Comparison of irrigant penetration depth between 30 4% & 30 6% in flat ended and side vented needles (t-test).

Group	Taper	Mean	StdDev	SE of Mean	Mean Difference	t	P-Value
Flat ended needles	30 4%	1.62	0.67	0.10	0.600	4.549	<0.001*
	30 6%	1.02	0.58	0.09			
Side vented needles	30 4%	3.28	0.74	0.11	0.816	5.518	<0.001*
	30 6%	2.47	0.66	0.10			

*denotes significant difference; Higher mean irrigant penetration depth was recorded in 30 6% compared to 30 4% and the difference between them was found to be statistically significant (P<0.001).

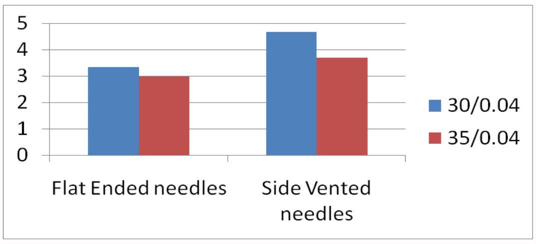


Graph 2:

Table 3: Comparison of irrigant penetration depth between the two needles in 30 4% and 35 4% (t-test).

Taper	Needle	Mean	StdDev	SE of Mean	Mean Difference	t	P-Value
30 4%	Flat Ended	3.36	1.25	0.39	-1.319	-2.701	0.015*
	Side Vented	4.68	0.91	0.29			
35 4%	Flat Ended	2.99	1.22	0.39	-0.725	-1.576	0.015*
	Side Vented	3.71	0.79	0.25			

*denotes significant difference; Higher mean irrigant penetration depth was recorded in flat ended needles compared to side vented needles and the difference between them was found to be statistically significant (P<0.05).



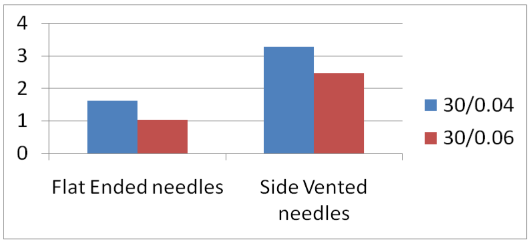
Graph 3:

significant (p<0.001) irrigant penetration compared to 30/0.04 (Table 2 and Graph 2). When irrigant penetration was compared between flat ended and side vented needles it was found that flat ended needles performed better than latter in both 30 and 35 apical size, and 4% and 6% taper which was statistically significant (p<0.001) (Table 3 and 4; Graph 3 and 4).

Table 4: Comparison of irrigant penetration depth between the two needles in 30 4% and 306%: (t-test).

Taper	Needle	Mean	StdDev	SE of Mean	Mean Difference	t	P-Value
30 4%	Flat Ended	1.62	0.67	0.10	-1.667	-11.182	<0.001*
	Side Vented	3.28	0.74	0.11			
30 6%	Flat Ended	1.02	0.58	0.09	-1.451	-11.111	<0.001*
	Side Vented	2.47	0.66	0.10			

*denotes significant difference; Higher mean irrigant penetration depth was recorded in flat ended needles compared to side vented needles and the difference between them was found to be statistically significant (P<0.001).



Graph 4:

Discussion

It is of essential importance that the root canal treatment, besides mechanical cleaning and shaping procedures, includes simultaneous chemical processing [18,19]. Even though endodontic files, both manual and rotary, are constantly improved [20] up to 40% of root canal surface may remain intact after mechanical processing. In terms of physical removal of material from the root canal, irrigation efficiency depends on the possibility of proper application of irrigation system, or proper depth, irrigation dynamics, irrigant quantity, and irrigant fluid characteristics. Irrigation needles, such as closed-end, side-vented, or notched open-end needles, vary in diameter and are specifically designed and intended for use in endodontics [21]. It was recommended that the needle should be applied to the WL of instrumentation, or a mm shorter or at least in apical third, in the root canal for flushing efficiency and removal of unwanted content from the root canal [13,22]. These results led to the conclusion that it was necessary to increase apical preparation size and taper [23] to place the tip of the irrigating needle as close as possible to the apical third of the canal to be more effective. Chow [10] found that the effectiveness of irrigation was a function of needle penetration depth and that the distribution of solution beyond the tip of the needle was much less than expected. Studies have demonstrated that the removal of canal debris was dependent on canal size, diameter of irrigating needle, and its depth of penetration into the root canal. A study by Boutsioukis et al. [24] showed that irrigant replacement till WL occurred if kept 1 mm short of WL in side vented needles and 2 mm to 3 mm short in open-ended flat needles. In order to maintain equal pressure and time of irrigation for standardization, dye was injected at the rate of 1 ml in 30 sec in all cases by the same investigator. The results of phase I of this study showed that when both flat open ended needles (group A) and side vented needles (group B) were used, increasing the apical preparation size from 30 to 35 increased the irrigant penetration but was statistically insignificant (p>0.05) (Table 1 and Graph 1). Root canals are typically 0.5 mm to 2 mm in diameter at the crown and taper down to less than 0.3 mm in mature roots [21]. The external diameter of the 30G needle is 0.3 mm which corresponds to 30 size instruments. Increased needle and irrigant penetration to the apical part of the canal was observed in both 30 and 35 size root canals. A number of studies have shown instrumentation to files larger than #30 reduces the bacterial counts, enhances the antibacterial effects of intracanal irrigants and prevents late bacterial growth after cleaning and shaping of root canals [25,26]. Wu and Wesselink [27] and others [28-30] have recommended enlarging the root canals to size over #40 file removes more debris from the canals and achieve better cleaning in the apical third of the root canals. However, instrumentation to these sizes increases the risk of perforation, ledge, and transportation, especially in narrow and curved root canals. The results of phase II of the study showed that in both the groups, increasing the apical preparation taper from 4% to 6% increased the irrigant penetration which was statistically significant (p<0.001) (Table 2 and Graph 2). Similar results were seen in other *in vitro* studies that have found irrigant penetration and shear wall stress increased as the root canal taper increased while reducing the risk for irrigant extrusion [14,31]. Greater file taper allows for the introduction of irrigant and subsequent removal of debris while keeping the apical foramen small. Khademi et al. [14] reported that apical instrumentation up to #30 file with 6% coronal taper is effective for the removal of debris and smear layer from the apical portion of root canals. In this study also increase in root canal taper allowed for deeper penetration of the irrigation needle and improved irrigant replacement. It was found that the flat ended needles performed better than the side vented needles in terms of irrigant replacement in both phases of treatment which was statistically significant (p<0.001) (Table 3 and 4; Graph 3 and 4). In this study the flat open ended needles were placed 2 mm short of WL and side vented needles 1 mm short or where the needle first binds to the canal. In an *in vitro* study done by Boutsioukis et al. [21], it was reported that the side vented needle achieved irrigant replacement to the WL only at the 1 mm position, whereas the open-ended flat needle was able to achieve complete replacement even when positioned at 2 mm short of the WL. This is in contrast with the present study as neither of the needles allowed irrigant penetration to the WL at the above mentioned position. The difference could be attributed to this being a clinical study; as well as the varied amount of pressure applied during irrigation. The mean irrigant penetration in side vented needle was short of the working length (2.47 mm) compared to flat ended needle (1.02 mm) which was statistically significant (p<0.001). Studies have shown that needle designs with safety features yielded significant lower apical pressure compared to open ended needles [32]. Hence, the irrigant penetration was closer to working length in flat ended needles. Root canal behaves as a close end micro channel; this results in gas entrapment at its closed end producing vapor lock which prevents the irrigant to reach the WL effectively [33]. Since there was no apical extrusion of the irrigant in any of the case, it can be suggested from this study to place needle closer to WL in side vented and flat open ended needles to improve irrigant penetration clinically. All the teeth used in this study had relatively straight roots; but complete irrigant penetration to WL could not be achieved. Strict standardization is difficult to achieve in *in vivo* studies as there are variations in shape, size, curvatures and length of canal might have influenced the results which led to the binding of needle to the canal in few cases. Many studies have proved that maintaining apical patency improves the delivery of irrigants into the apical third of root canals [34,35]. Also, manual dynamic agitation (the use of a well-fitting gutta-percha cone for manual agitation of an irrigant-filled canal) [36,37] has the potential to displace the apical gas entrapment from a closed system. Further *in vivo* studies are required to determine the needle-insertion depth of flat open ended and side vented needles. It must be understood that achieving larger taper is not always practical. Curved canals are frequently encountered clinically and are more difficult to clean and shape. Achieving a 6% tapered preparation in curved roots may be impractical in the majority of cases.

Conclusion

- Within the limitations of the study it can be concluded thatIn both flat open ended needle and side vented needle group, increasing the preparation size of the DB canal from 30 to 35 increased irrigant penetration but was statistically insignificant (p>0.05).

- In both flat open ended needle and side vented needle group, irrigant penetration in 6% taper of DB canal was significantly better than 4% (p<0.001).

- Flat open ended needles performed significantly better than side vented needles in both phase I and II of the study (p<0.001).

Hence it can be concluded that an apical preparation size of 30 and 6% preparation taper seems to maintain a good balance of tooth structure preservation and adequate irrigation penetration depth at the apical third when using the conventional needle and syringe system with flat open ended needles performing better than side vented needles.

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