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Evaluation Of Apical Vapor Lock Formation and Comparative Evaluation of Its Elimination Using Four Different Irrigating Techniques: An In Vitro Study

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ABSTRACT

Aim:

The aim of this study was (1) to evaluate the formation of air bubbles (apical vapor lock) in the apical third of root canal during syringe irrigation, using cone beam computed tomography (CBCT) and (2) Comparative evaluation of the elimination of an established vapor lock during syringe irrigation by Manual dynamic agitation (MDA), Sonic (PATS), Passive ultrasonic irrigation (PUI), Apical negative-pressure irrigation system (EndoVac) using CBCT.

Materials and methods:

A total of 48 extracted human single-rooted lower premolars were radiographed to ensure that each tooth contained one canal. Each tooth was decoronated at 18mm from the anatomic apex. Patency of the canal was achieved with a no. 10 K-file. Working length established at 1mm short of the apical foramen.To create a closed canal system, the cementum of each root was coated with tray adhesive. The root tip was coated with flexible, hot glue which was allowed to solidify, and then the tooth was mounted in putty impression material. Each root was prepared using crown down technique to size F2 Protaper Gold; 3%NaOCl was delivered with a 30-G side vent needle which was placed 1 mm short of the working length at the rate of 3ml/minute. 17% liquid Ethylenediaminetetraacetic acid (EDTA) was used as the final irrigant to remove the smear layer; 5 ml of 17% EDTA liquid was delivered with the 30-G needle and left in the canal for 5 minutes. Each canal was then subsequently irrigated with 5ml of deionized water and dried with paper points. During instrumentation, files were coated with RC Prep for lubrication.

All the teeth were irrigated with 5ml of contrasting media 8M cesium chloride + 3% sodium hypochlorite mix in equal proportions, delivered through the 30-G needle 1mm short of the working length. The needle has removed the teeth were placed under a CBCT scanner and snapshots were obtained to check for apical vapor lock. The formation of vapor lock was verified in the CBCT scanner, and the teeth were divided into 4 groups. Group 1: Manual Dynamic Agitation (MDA), Group 2: Sonic irrigation (Pro Agitator Tip System), Group 3: Passive ultrasonic irrigation (Irrisafe Tip), Group 4: Apical negative-pressure irrigation system (EndoVac). The teeth were again placed in a CBCT scanner and results were analyzed using the chi-square test.

Results:

Apical vapor lock was formed in all the 48 samples analyzed. In the present study apical negative-pressure irrigation system (EndoVac) eliminated vapor lock in 83.3% of the samples followed by MDA which eliminated vapor lock in 75% of the samples, PUI (Irrisafe) with 33.3% and Sonic (PATS) with 25%.

Conclusion:

Within the limitations of this study, it can be concluded that:(1) Apical vapor lock is consistently formed after positive pressure irrigation in a closed canal system. AVL prevents complete debridement of the root canal system. (2) Negative pressure irrigation technique was most effective in removing apical vapor lock (3) MDA was comparable to Endovac in removing apical AVL, but was not statistically significant ($p > 0.05$). (4) MDA performed better than PUI and sonic in eliminating AVL, with statistically significant difference between the three groups ($p < 0.05$). (5) PUI activation performs better than sonic. Sonic was the least effective in removing AVL.

Keywords : Apical Vapor Lock Formation, Vitro Study.

INTRODUCTION

Aim of modern endodontics is to obtain complete debridement of the root canal system. The root canal system is complex enough to perplex, challenge and sometimes frustrate even the best of clinicians. There can be no doubt today that microorganisms, either remaining in the root canal space after treatment or re-colonizing the filled canal system, are the main cause of endodontic failure. A thorough cleaning and shaping is mandatory for optimum disinfection. 'Files shape, Irrigants clean' is the current concept in endodontics.[1] The long-term success of endodontic treatment is closely linked to adequate cleansing of the endodontic space after root canal

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shaping, and then proceed to a complete obturation of the root canal system.[2] Since roots are surrounded by periodontium, a root canal resembles and behaves like a close-ended channel. This produces an apical vapor lock effect wherein there is air entrapment by an advancing liquid front in closed-end microchannels. Thus, there is air bubble formation in the apical end of the root canal, which precludes adequate disinfection. These microchannels (root canals) will be flooded eventually with the fluids (irrigants) after a sufficient time period, which can extend from hours to days. Thus, as such the vapor lock effect is not a permanent one. However, this phenomenon has practical clinical implications, since endodontic treatment is performed within a short time span. So, there is inadequate time for complete flooding of the fluid (irrigant) in the channel (root canal) to occur. Thus, the flow of irrigant is hindered in the apical third, resulting in inadequate debridement of the canal system.[1]

The current study is taken up using four different irrigation techniques in terms of evaluating the formation and elimination of the apical vapor lock, which is a very critical aspect of irrigation in endodontics.

MATERIALS AND METHODS

Experimental Design

A total of 48 extracted human single-rooted lower premolars were radiographed to ensure that each tooth contained one canal. A diamond disc was used to decoronate the samples so as to standardize the working length. Each tooth was decoronated at 18mm from the anatomic apex. Patency of the canal was achieved with a no. 10 K-file. Working length established at 1 mm short of the apical foramen. To create a closed canal system, the cementum of each root was coated with tray adhesive. The root tip was coated with flexible, hot glue which was allowed to solidify, and then the tooth was mounted in putty impression material. Each root was prepared using crown down technique to size F2 Protaper Gold; 3% NaOCl was delivered with a 30-G side vent needle which was placed 1 mm short of the working length at the rate of 3ml/minute. 17% liquid Ethylenediaminetetraacetic acid (EDTA) was used as the final irrigant to remove the smear layer; 5 ml of 17% EDTA liquid was delivered with the 30-G needle and left in the canal for 5 minutes. Each canal was then subsequently irrigated with 5 ml of deionized water and dried with paper points. During instrumentation, files were coated with RC Prep for lubrication. All the teeth were irrigated with 5ml of contrasting media 8M cesium chloride + 3% sodium hypochlorite mix in equal proportions, delivered through the 30-G needle 1mm short of the working length. The needle was removed the teeth were placed under a CBCT scanner and snapshots obtained to check for apical vapor lock. The formation of vapor lock was verified in the CBCT scanner, and the teeth were divided into 4 groups of 12 teeth each.

In Group 1, Manual Dynamic Agitation (MDA), a well-fitting greater taper gutta-percha cone is moved up and down the instrumented canal containing the irrigant in short 2 to 3mm strokes. The frequency of the push–pull motion was 100 strokes per 30 seconds. MDA was performed using a No. 20.06 gutta percha 1 mm short of working length and agitated in and out 2 to 3 mm for 1 minute.

In Group 2, Sonic irrigation (Pro Agitator Tip System), the handpiece and tip are mounted on air rotor coupling. The water connection is switched off. The Pro-agitator tip is used with the irrigant in the root canal system. Sonic irrigation was performed with no.25 tip with a tip diameter of 0.025mm and length 25mm for 1 minute at 1mm short of the working length.

In Group 3, Passive ultrasonic irrigation (Irrisafe Tip), Passive ultrasonic irrigation (Irrisafe; Satelec, Acteon equipment) was performed using Irrisafe tip. A No.25 ultrasonic file of length 25mm was inserted at 1 mm short of the working length and activated by performing withdrawal movements to flush the irrigant upwards for 1minute at a medium power setting.

In Group 4, Apical negative-pressure irrigation system (EndoVac), Micro Cannula is inserted 1mm short of WL and NaOCl is delivered from MDT. The master delivery tip (MDT) delivers 1ml of NaOCl into the access cavity; simultaneously the microcannula is passively introduced 1mm short of the working length under apical negative pressure for a period of 1minute. The Micro Cannula is removed immediately before removing the MDT, leaving the canal filled (charged) with NaOCl. The samples in each group were subjected to a different irrigating technique and were again placed under a CBCT scanner and snapshots obtained.

All results were tabulated and statistically analysed.

Statistical Analysis

The data were analyzed using Chi-square test. The statistical significance was set at $p \leq 0.05$. The statistical analyses were performed using Statistical Package for the Social Sciences version 15.0 software.

RESULTS

Apical vapor lock was formed in all the samples. Out of the 12 teeth in each group, the apical vapor lock was eliminated in 9 samples of MDA (group I), 3 samples of Sonic (PATS), 4 samples of PUI (Irrisafe) and 10 samples of ANPIS (EndoVac).

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Table 1: Frequency table of vapor lock elimination by four different techniques of agitation

Technique (12 Teeth each)	**Vapor lock eliminated**	**Vapor lock not eliminated**
Manual Dynamic Agitation	**9**	**3**
Sonic (PATS)	**3**	**9**
Passive Ultrasonic Irrigation (Irrisafe)	**4**	**8**
ANPIS (EndoVac)	**10**	**2**

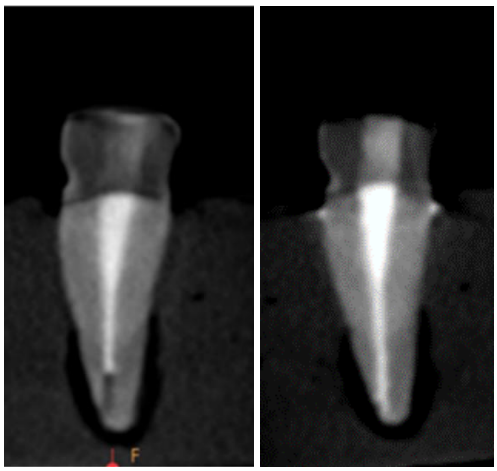

Fig 1:Vapor lock eliminated using Manual Dyanamic Agitation

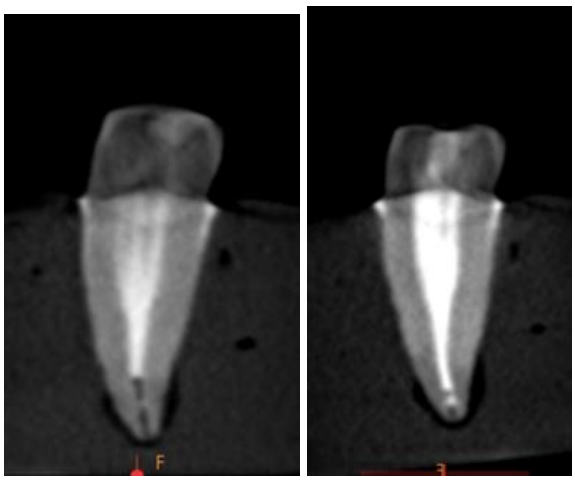

Fig 2:Vapor lock seen in PATS system

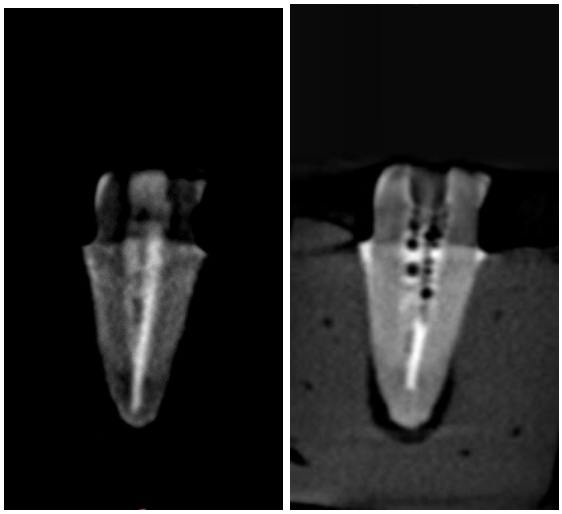

Fig 3:Vapor lock seen in PUI

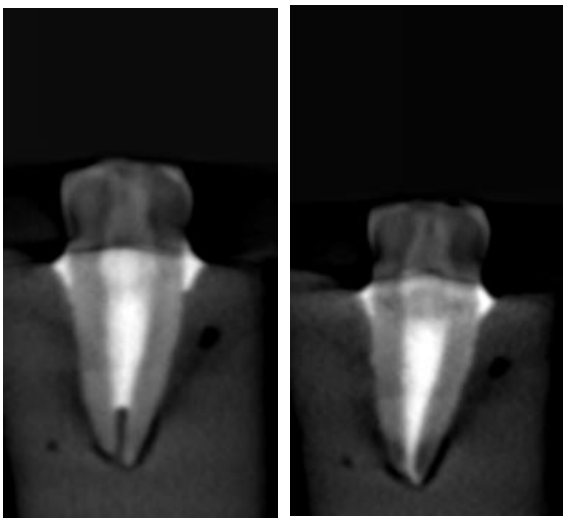

Fig 4:Vapor lock eliminated using

DISCUSSION

The area of focus is the irrigation of the apical third of root canal system as the importance of apical one-third irrigation is multifold.[3] The root canal behaves like a close ended system since the roots are covered by periodontium. Thus, there is air entrapment by an advancing liquid front in closed-end microchannels. This is termed as Vapor lock effect. Sodium Hypochlorite is the most widely used irrigant to clean and disinfect the uninstrumented areas of the root canal system. When Sodium Hypochlorite irrigant reacts with the organic tissue of dentinal walls it causes hydrolysis, which liberates carbon dioxide and ammonia. This results in micro gas bubbles in the apical portion of the root canal that coalesce into a large apical vapor bubble. This gas bubble gets trapped in the apical region and quickly forms a column of gas into which further fluid penetration is impossible. Even extension of instruments into this vapor lock does not reduce or remove the gas bubble, just as it does not enable adequate flow of irrigant. Since vapor lock effect is usually seen in the apical region of the root canal which is known to have numerous lateral canals, ramifications, anastomosis, webs, fins, apical deltas and multiple portals of exit, it is important to eliminate apical vapor lock.[1]

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Apical vapor lock seems to be more frequent in narrow canals but earlier studies probably overestimated its frequency by inserting the needle way to far from the working length, irrigating at low flow rates or using artificial root canals made of hydrophobic materials.[4] Various investigation methods such as direct observation of the sample, periapical radiography and stereoscopic microscope have been used to study the vapor lock effect. However, the use of a two-dimensional radiograph to evaluate air bubbles in a three-dimensional system may have resulted in some inaccuracy.

The present study was performed to compare four irrigating systems MDA, Sonic, Ultrasonic and apical negative-pressure irrigation system (ANPIS) in terms of eliminating the AVL in an ex-vivo model simulating the clinical situation.

In the current study, a closed system design was followed. Each root was instrumented to size F2 Protaper Gold and mounted on Putty impression material to mimic the exact clinical scenario as most of the routine endodontic cases behave as a close ended system. Conservative preparation of the canal was maintained as excessive preparation at the tip can result in over enlargement or perforation of the apical foramen converting it into an open ended system which can cause variations in the results. This can also result in reduction in radicular dentin thickness and subsequent weakening of the root structure.[5]

A 30 gauge single side vent needle was used for syringe irrigation during the entire procedure. Apical vapor lock was formed in all the 48 samples analyzed. These were divided into 4 groups of 12 samples each.

In the present study negative pressure irrigating system showed elimination of vapor lock in 83.3% samples, followed by MDA with 75%, then PUI with 33.3% and the least was sonic with 25%.

The results of this study are not in agreement with the studies done by Agarwal et al. on comparative evaluation of the elimination of an established vapor lock by Sonic, ultrasonics, and manual dynamic agitation. In his study removal of vapor lock occurred in 50% of the cases using MDA and 90% with sonic. The difference might be because in their study MDA was performed using K-files, which probably produced a different result than when using gutta-percha cones. When a gutta-percha cone with the same diameter and dimension as the shaped canal is used, it is possible to push the liquid beyond the bubble without producing a fragmentation and an endoactivator was used for sonic irrigation system whereas we have used the PATS. In comparison a similar study by Su et al. MDA and photon-induced photoacoustic streaming (PIPS) a laser-activated irrigation technique showed a 100% reduction of AVL when compared to PUI with 70.37% and Sonic with 63.54%.

The most recent study investigating the removal of vapor lock was that by Mario Dioguardi et.at comparing the efficacy of two methods: manual dynamic agitation (MDA) and passive ultrasonic irrigation (PUI) in 50 endo training blocks, which were divided into two groups of 25 samples each. The MDA method produced 80% reduction in vapor lock, whereas the PUI method yielded a 55% reduction.

PUI method is not able to remove the vapor lock effect but can only reduce fragmenting bubbles, whereas MDA is an effective system. PUI remains an excellent method to activate canal irrigants but produces only modest results for the removal of AVL when compared with MDA.

The selection of a guttapercha cone that corresponds to the canal preparation size and taper ensures that air inside the apical third of the canal gets displaced when the guttapercha is inserted to working length. The push-pull motion of a snugly fitting master cone probably generates higher intracanal pressure, thereby carrying the irrigant to the "untouched" canal surfaces. The frequency of this technique (3.3 Hz, 100 strokes per 30 seconds) is higher than that of automated-dynamic irrigation systems (1.6 Hz), possibly generating more turbulence in the canal. It acts by physically displacing, folding, and cutting of fluid under ‘‘viscously-dominated flow’’ in the root canal system. It allows the irrigating solution to flow up and down along the cone, with the solution being displaced outward when the cone is inserted at length and flowing inward when it is removed. This enables better mixing of the fresh unreacted solution with the spent, reacted irrigant. This could be a possible reason for MDA performing better that sonic and ultrasonic systems.[1,6]

Pro-Agitator system which works on air sonics was used for sonic irrigation with a 0.025mm tip diameter. PATS operates at 6000Hz and has a three dimensional movement of the tip which causes enhanced acoustic streaming. However, it was unable to eliminate the vapor lock in most of the samples. In the present study vapor lock was eliminated in only 25% of the samples. Sonics and ultrasonic activation are proving to be an effective method for disinfecting root canals. Sonics and Ultrasonics function on the principle of acoustic microstreaming and cavitation. Acoustic microstreaming is the movement of fluids along cell membranes, which occurs as a result of the ultrasound energy creating mechanical pressure changes within the tissue. Cavitation refers to the formation and collapse of gas and vapor filled bubbles or cavities in the fluid. Thus, acoustic streaming and cavitation can only occur in a liquid phase, i.e in fluid, and not in gases. Hence, once a sonic or ultrasonically activated tip leaves the irrigant and enters the apical vapor lock, acoustic microstreaming and/or cavitation becomes physically impossible.[1,7] This could be a probable reason for the superior action of MDA when compared with sonic and ultrasonic activation.

No studies are reported comparing removal of apical vapor lock using negative pressure irrigation technique. Most studies are done comparing negative pressure irrigation technique with smear layer removal or debris removal in the apical one-third of the root canal system. These studies have co related that ineffectiveness in

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debridement in apical area might be due to AVL. ANPIS allows penetration of irrigant to full WL, it eliminates vapor lock and ensures sufficient irrigant penetration up to the root apex.

EndoVac was used as a negative pressure irrigation system. The EndoVac system is an apical negative pressure irrigation device that is designed to drain irrigating solutions at the apical third of canal by overcoming the vapor lock effect. EndoVac eliminated vapor lock in 83.3% of the samples. EndoVac performed significantly better than sonic and PUI in eliminating vapor lock. However, the proportion vapor lock eliminated did not differ significantly when compared between Manual Dynamic Agitation and EndoVac. We have used only the microcannula, which was placed 1mm short from the working length for 1min. The macrocannula which is used for gross debridement was not used as we had already completed the cleaning and shaping. Since the primary focus was removal of vapor lock thereby facilitating irrigant penetration upto the apex, the microcannula alone was used in the study. EndoVac works on suction rather than forceful pushing of irrigant into the canal. The microcannula is placed 1mm short from the working length simultaneously 1ml of irrigant is delivered through the master delivery tip. The suction pulls the irrigant and at the same time prevents extrusion of irrigant beyond the apex.

Apical vapor lock prevents complete debridement of the root canal system.[8] Irrigation system and techniques must maintain a balance between two important goals safety and effectiveness. The AVL and consideration for the patients safety have always prevented the thorough cleaning of the apical third. Very few studies are done to check AVL using sonic, ultrasonic and negative pressure techniques.

Many studies have been done to check debris extrusion, smear layer removal, antimicrobial action of irrigants in the apical end of the root canal. Various techniques like needle irrigation (open ended or side vented), MDA, PUI, sonic, negative pressure irrigation using both ‘open system’ and ‘close system’ are reported. A few of these have co-related failure of adequate disinfection of the apical portion due to the inability of irrigant to reach the apical third because of the vapor lock effect.

The results of our study showed apical negative-pressure irrigation most effective (83.3%) in eliminating AVL followed by MDA (75%), then PUI (33.3%) and least effective was sonic (25%). Though the results of our study for the removal of AVL are promising when irrigants are activated using ANPIS. One lacunae that we have been unable to address is the comparison with similar studies. Hence further comparative studies with a larger sample size are required to assess the efficacy of different irrigation activation techniques for the removal of AVL.

Conclusion:

Within the limitations of this study, it can be concluded that:

1. Apical vapor lock is consistently formed after positive pressure irrigation in a closed canal system. AVL prevents complete debridement of the root canal system.
2. Negative pressure irrigation technique was most effective in removing apical vapor lock
3. MDA was comparable to Endovac in removing apical AVL, but was not statistically significant ($p > 0.05$).
4. MDA performed better than PUI and sonic in eliminating AVL, with statistically significant difference between the three groups ($p < 0.05$).
5. PUI activation performs better than sonic. Sonic was the least effective in removing AVL.

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