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Apical Vapour Lock Effect in Endodontics – A Review

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ABSTRACT

Microbial eradication from the root canal system is essential for successful endodontic therapy. Irrigants play a major role in achieving this objective. In order to achieve optimum results, an irrigant has to penetrate into all the areas of the root canal system. The challenges to thorough irrigation include the complex pulp space anatomy, penetration of irrigating needle, chemical interactions of irrigants and preventing overextrusion of irrigants. Apical vapour lock effect also hinders irrigants from penetrating the apical third of the root canals. This article attempts to shed light on the apical vapour lock effect and methods to prevent or eliminate it.

Keywords: Apical Vapour Lock, Irrigation, Sodium Hypochlorite.

INTRODUCTION

The root canal system is complex enough to perplex, challenge and sometimes frustrate even the best of clinicians.[1] 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. The primary endodontic treatment goal must thus be to optimize root canal disinfection and prevent re-infection.[2] A thorough cleaning and shaping is mandatory for optimum disinfection[3] ' Files shape, irrigants clean' is the current concept in endodontics

The importance of irrigation in endodontics cannot be overemphasized, as an irrigant can touch areas in the root canal that an endodontic instrument cannot. The term 'excessive irrigation' does not exist in endodontic parlance. There is an overall consensus that volume of irrigant is the most important criteria during irrigation. In fact, Schilder in 1974 advocated an average of 39 ml of NaOCl per visit, to clean the root canal space. Schilder's irrigation protocol became the benchmark of excellent clinical treatment. Chow (1983) put forth an infallible paradigm for endodontic irrigation: 'For the solution to be mechanically effective in removing all the particles, it has to a) reach the apex, b) create a current, and c) carry the particles away.'

It is critically important to develop an irrigation protocol wherein the irrigant penetrates into all areas of the root canal, including the apical ramifications, isthmi, fins and deltas. It is easier said than done. Apical vapour lock effect is one such major hindrance in achieving this objective.

APICAL VAPOUR LOCK EFFECT

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 vapour 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.[4]

Apical vapor lock also results in gas entrapment in the apical portion. Sodium Hypochlorite irrigant reacts with the organic tissue of dentinal walls, causing hydrolysis, which liberates carbon dioxide and ammonia. This forms micro gas bubbles in the apical portion of the root canal that coalesce into a large apical vapour bubble. This gas bubble gets trapped in the apical region and quickly forms a column of gas into which further fluid penetration is impossible. 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.

If the tooth apex is oriented in upward direction, i.e. in maxillary teeth, the gas bubble cannot escape into the apical tissues. In mandibular teeth, where the apex is oriented downwards, the weight of the irrigant traps the gas bubble and its surface tension force resists the buoyancy force of the trapped gas.

Hence the apical vapour lock (AVL) cannot be displaced within a clinically relevant time frame through simple mechanical actions; and it prevents adequate disinfection of the most critical area of the root canal, i.e. the apical third.

The phenomenon of apical vapor lock has been confirmed in studies where roots were embedded in a polyvinylsiloxane impression material to restrict fluid flow through the apical foramen, simulating a close-ended channel.

The currently available evidence strongly favors sodium hypochlorite as the main endodontic irrigan. Its tissue dissolution capacity and antibacterial efficacy has made

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it the gold standard amongst irrigants.[5-9] Since there is no suitable replacement for NaOCl, it is all the more imperative that the AVL problem be addressed.

EARLY RESEARCH ON AVL

Senia (1971) tested 5.25% NaOCl in a 'closed tooth model' where the apex was sealed with green stick compound. The root canals were enlarged to instrument #30. Histological examination revealed substantial residual pulp tissue in the apical region. The study concluded that 'The value of NaOCl as an irrigating agent for dissolving pulp tissue in the apical 3 mm of narrow root canals is questionable."

Salzgeber and Brilliant (1977) carried out a similar study; only they enlarged the canals apically upto size 35 and used a radiopaque dye (Hypaque) instead of NaOCl. Their study showed that the irrigant reached the apex when the canals were opened larger than a size 30 file. The flaw with this study was that Hypaque is inert and did not react with the organic materials, while NaOCl hydrolyzed organic materials, releasing NH3 and CO2, and formed AVL in a closed root canal system[2]

In subsequent years, a plethora of irrigation-related studies were published. Numerous irrigants, their volume, concentration, temperature, their combinations, irrigating regimes and protocols were tried and tested.

Once the deleterious effects of AVL in "closed systems" were established, the clinical relevance of the conclusions drawn from "open system "designs was questioned. Scores of studies were done in which the root canal was not closed at the apical end. Most studies carried out with open systems presented lesser AVL than closed systems. It is only in recent years that researchers have emphasized the "closed system" model for studies. In fact, studies conducted without ensuring a close-ended channel cannot be regarded as conclusive on the efficacy of irrigants and the irrigant system.

Many studies used radiopaque agents with irrigants, to study AVL by IOPA or micro CT. (de Gregorio et al. 2009, Tay et al. 2010, Vera et al. 2012, Peeters and Gutknecht 2013) This may have led to a change in density, viscosity, surface tension and contact angle on dentinal wall thus giving inaccurate results.

Some researchers used tooth clearing techniques to render the roots transparent for direct visualization of AVL (de Gregorio et al. 2009, Robertson et al. 1980, Venturi et al. 2003). These, too, led to altered dentinal physical properties because of the clearing technique. The dentine surface of such teeth would probably be less hydrophilic with a higher contact angle than normal dentine. This would favour more bubble entrapment and therefore impact the results.[10]

Studies were also carried out using acrylic resin blocks in place of teeth. These resulted in altered surface properties, and primarily a more hydrophobic behaviour, with higher irrigant contact angle. (Ihrig and Lai 1957, Good and Koo 1979, Rubio et al. 1991, Hu et al. 2010). There would be no interaction of NaOCl with inorganic components leading to gas entrapment. All the above studies gave erroneous results as they did not mimic actual clinical conditions.[11]

EFFECT OF VARIOUS IRRIGATION TECHNIQUES ON AVL

Today's irrigation armamentarium presents a diverse variety of tools and techniques that can assist the practitioner in reducing bacteria and debris within the canal system. However, currently there is no universally accepted standard irrigation technique.[4]

Chow (1983), determined that traditional positive pressure irrigation had virtually no effect apical to the orifice of the irrigation needle in a closed root canal system. Fluid exchange and debris displacement were minimal. It is now proven that an irrigant can reach only 1-1.5 mm beyond the tip of the needle[12] The only option is to use smaller diameter needles and their insertion to within 1 mm of working length, which can prove to be hazardous in terms of inadvertent periapical extrusion. NaOCl, if thus extruded can cause extensive damage. Even use of side vented needles had no significant effect on AVL. Researchers have concluded that these bubbles cannot be removed by conventional syringe irrigation. (de Grego- rio et al. 2009, Gu et al. 2009, Tay et al. 2010)

Mechanical agitation techniques during irrigation with files, brushes, etc also have proved unsuccessful in dislodging AVL. Trying to 'puncture' it with an instrument or needle, only ends up making the space smaller, and increases the surface tension.

Sonics and ultrasonic activation are proving to be an effective method for disinfecting root canals[13] 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.[14]

A simple method to disrupt the vapor lock might be achieved by the use of a gutta percha master cone that is introduced to working length after instrumentation and hand –activated in up and down motions. This method, although cumbersome, eliminates the vapor lock because the space previously occupied by air is replaced by the root filling material, carrying with it a film of irrigant to the working length.[15] This technique is described in detail later.

Apical negative pressure technique is another effective method to eliminate the apical vapor lock. This method has also been proven to be safe because it always draws irrigants to the source via suction—down the canal and simultaneously away from the apical tissue in abundant quantities[16] This results in safer delivery of irrigants, less overextrusion, greater debris removal and a cleaner result at working length. The Rinsendo Irrigation System (Rinsendo, Co. Duerr- Dental, Bittigheim-Bissingen, Germany) and the EndovacSystem designed by Dr. G. John Schoeffel are examples of negative pressure irrigation techniques.[17,18]

In Endovac system, placement of the macrocannula at middle–apical third of the canal, followed by the placement of the microcannula to working length, enables the irrigant to be suctioned in sufficient volume and flow to remove smear layer and eliminate AVL.

Endo Irrigator Plus (K Dent Dental System) is an irrigating system based on ACWIS (Activated continuous warm irrigation and evacuation system) concept. In this unit NaOCl is warmed upto 45°. This device creates positive and negative pressure inside the canal. Positive pressure irrigation with warm NaOCl cleans and disinfects up to the middle third, and removes all macro debris. Negative pressure irrigation with warm NaOCl cleans and disinfects upto apical third, removing all micro and nano debris. Trials done under electronic microscope found that this device actually helps penetration of NaOCl into the lateral and accessories canals. Strong vacuum evacuation system prevents overextrusion of NaOCl.[19,20] This irrigation system has also proved effective against AVL.

Since improper irrigation of apical third of root canals can lead to compromised endodontic outcomes, a clinician should try his best to prevent or eliminate the AVL.

METHODS TO ELIMINATE/PREVENT AVL

Achieve apical patency-During instrumentation, dentin chips produced by instruments and fragments of apical pulp tissue tend to get compacted into the foramen, which cause apical blockage. Therefore, establishing apical patency is leaving the apical foramen accessible, free from dentin chips, pulp fragments and other debris. It can be achieved with a small size file, which moves passively through the foramen. The patency filing technique may be considered an important step in preventing AVL[21]

Apical size of root canal. The need for adequate enlargement of the root canal to improve irrigation efficacy was recognized by Grossman as early as 1943[22] Larger the apical size of the root canal, lesser is the chance of AVL formation. However, the drawbacks of over- enlargement of the canal viz. reduction in radicular dentin thickness and subsequent weakening of the root structure, should be considered before deciding on the apical size[23]

Size of irrigating Needle tip and its extent in the root canal - Commercially available needles of size 27G, 30G or 31G may facilitate insertion of the needle tip close to the working length in most cases. A 27 G needle has an outer diameter of 0.41 mm (corresponds with ISO size # 40 endodontic instrument), 30 G and 31G needles have outer diameters of 0.31mm (size# 30) and 0.26mm (size # 25) respectively.

A 27 gauge needle is the most preferred needle tip size for routine endodontic procedures. The tip must extend as close to working length as possible, taking care that there be no periapical extrusion of the irrigant.

Irrigant flow rate - Higher flow rates were correlated to decreased AVL. Nevertheless, a higher flow rate has also been linked to increased irrigant pressure at the apical foramen (Verhaagen et al. 2012), with increased risk of irrigant extrusion. So flow rate should be adjusted according to the irrigation technique used.

Some researchers suggest that exceeding a rate above 4 ml/min does not improve apical clearance but does increase the risk of extrusion; therefore 1 ml increments over 15 seconds give maximum exchange and minimum risk[21,24]

Use flexible needles/tips in curved canals- In narrow curved canals, introduction of a syringe apically may be impossible. Flexible or NiTi tips are available that can negotiate curved canals more easily. Pre-bending of needles also can be done in curved root canals.

Manual dynamic agitation - Following instrumentation, the canal is filled with irrigant and the gutta percha master cone inserted. It is then ‘pumped’ up and down in rapid 3 mm motions. This can overcome AVL and facilitate irrigant exchange close to the final working length, while at the same time disinfecting the GP cone prior to cementation. This technique is the simplest and easiest method of tackling AVL. Several studies have demonstrated that manual-dynamic irrigation is significantly more effective than an automated-dynamic irrigation system and static irrigation.

Manual dynamic agitation succeeds possibly because of the following factors:

a) 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.
b) The push-pull motion of a snugly fitting master cone probably generates higher intracanal pressure, thereby carrying the irrigant to the "untouched" canal surfaces.
c) 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.
d) 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.[15,25]
e) Technique is simplest and most cost effective.

Pressure alternation devices - The drawbacks associated with positive pressure irrigation like periapical irrigant extrusion, made researchers hunt for more suitable alternatives. Concomitant irrigant delivery and aspiration via the use of pressure alternation devices provide a plausible solution to this problem.

The RinsEndo irrigation system and the EndoVac irrigation system are examples of negative-pressure irrigation.

As mentioned earlier, Apical negative pressure irrigation with Endovac or Rinsendo irrigating systems or ACWIS (Activated continuous warm irrigation and evacuation system) using Endo Irrigator plus can prevent AVL.

CONCLUSION

To put it simply, AVL prevents complete debridement of the root canal system. Clinicians have been syringing irrigants into the root canal system with the belief that they were carrying it through the entire space, right down to the apical terminus. Nothing can be farther from the truth. SEM, Biological, light microscopy and other studies substantiate this fact. Irrigation techniques must maintain a balance between two important goals: safety and effectiveness. The AVL and consideration for the patient's safety have always prevented the thorough cleaning of the apical third. It is critically important to determine which irrigation system will effectively clean this critical area of the pulp space concurrently giving due respect to its immediate neighbours. A meticulous disinfection protocol will go a long way in ensuring endodontic success.

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