Review Article

Negative pressure irrigation system: A review

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ABSTRACT

Aim: The aim of this review is to analyze the data of treatment outcome and cleaning and disinfection of root canals by negative pressure irrigation systems. **Objectives:** The objective of this review is to comparatively analyze negative pressure irrigation systems available. **Background:** The etiology for the most endodontic disease is microbes. Apical periodontitis is most commonly caused by infected root canals. Hence, it is necessary to mechanically and chemically remove these microorganisms during root canal treatment. Irrigation forms a vital part of root canal debridement. The apical third of the system is the most difficult area to clean as it has complex network of complex space. Syringe irrigation is the most common method used by endodontist. Negative pressure irrigation is an alternative method that helps in dissolving the most critical part of root canals. **Reason:** The reason is to review and regain knowledge regarding the efficacy of negative pressure irrigation in root canal treatment.

KEY WORDS: Irrigation, Endo vac, Positive pressure, Negative pressure, Instruments

INTRODUCTION

Endodontics has reached a level where major developments and innovations are happening routinely. Needle ultrasonics, biocompatibility of filling materials, rotary devices, and imaging of the techniques have been undergoing major changes over the decades. However, the developmental changes in irrigating the root canal system have shown a slow progress. However, nowadays, we are seeing a developmental surge in advanced irrigation technology.[1] The endodontics has the ultimate goal in cleaning the root canal system effectively. The apical third of the root canal is the most critical area. This is due to the fact that the presence of deltas, fins, and canal spaces in the root canal makes it the highly complex anatomical network, making the instruments inaccessible. The apical third contains over 98% of the canal ramifications.[2]

The mechanical instruments which we used normally have less cleaning capability in the apical third of the root canal. Researchers are being indulged in various studies to invent a superior quality mechanical device which would be implemented in irrigation techniques to achieve an effective cleaning. In a research, it was reported that only 35% of the canal space walls have actually been contacted by the instruments.[3] These instruments are helping in creating a pathway in the canal system and are also helpful in allowing the chemical irrigants solutions to flow through the created path. Hence, we are now mostly dependent on the actions of these chemical agents to clean the complex canal space.[4]

The technique of positive pressure needle irrigation does not allow the solutions to reach the full length of the canal system effectively. The most important aspect to clean the apical area is to have a irrigant solution to create a force and with that force to reach the apical region and take the particles away from the apical third of root canal. However, these qualities are not present in classic technique.[5]

The apical negative pressure irrigation technique has changed the common grounds in apical irrigation. This technology could allow the chemical irrigants to reach the full working length of the root canal space. This irrigation technique creates negative pressure by suction method. The negative pressure created is used to pull the chemical solutions injected into canal space from the reservoir to the working length using high-speed suction. The high-speed suction at the tip of the cannulae drives the negative pressure current force. When the blockage of the cannulae occurred or

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disturbance to the suction force occurred, solutions would not be present in the apex. This is due to the dependent nature of the technology on the suction force to deliver the chemical solution to the full working length of the canal space.

This review of the negative pressure apical irrigation will show a descriptive difference with the positive pressure irrigation, technology used, how it is one of the most advanced canal cleansing, minimization of risks, and maximization of effectiveness and the clinical impact.

Objectives of Irrigation

The endodontic treatment has always kept its priority to eliminate or to prevent apical infection. Instruments are made to shape the canals to their convenience, and irrigants are injected into the roots to clean the canals. The irrigation of root canal system involves the canal filing and delivering chemical solutions to the full working length of the canal space safely. Irrigation of root canal has been aiming to eradicate the organic and inorganic contaminants.

Root canal irrigation may be divided into two techniques, manual and machine-assisted techniques. Manual irrigation involves the positive pressure in which syringe fitted with different needle designs and manual dynamic activation of irrigant solution. Machine-assisted techniques include sonics and ultrasonics. It also includes newer systems such as EndoVac, RinsEndo, EndoActivator, the Vibringe, and plastic Endo. Two important factors that determine the effectiveness of the irrigation are the ability of the irrigant delivery system to reach the apical terminal and the ability of the irrigant to remove the debris from the areas that could not be reached by the instruments. Nickel–titanium alloy is a crossover designs and has been adapted both for hand and rotary instruments. Various designs have been developed using nickel–titanium alloys. Nickel–titanium alloys possess super-elastic property which helps in retaining original shape even after undergoing deformation. The nickel–titanium wire is even more flexible. Nickel–titanium alloy possesses a modulus of elasticity that is one-fourth to one-fifth of that of stainless steel, allowing a wide range of elastic deformation.

IDEAL REQUIREMENTS OF IRRIGANTS

Irrigants are the chemical agents which are delivered into the root canals, and they used to dissolve the tissue remnants, to kill the microorganisms, and to clean the root canal effectively and safely without any consequences. The ideal irrigant solution should have the following properties:

1. It should have the broad antimicrobial action
2. It should be able to dissolve the necrotic pulp remnants
3. It should inactivate the endotoxins

It should have greater efficacy against the facultative and anaerobic organisms.

4. It should be able to prevent the smear layer from forming during instrumentation and to dissolve the smear layer if formed
5. It should be nontoxic to the system and vital tissues and should not cause pain in periodontal tissues and little anaphylactic property.

IRRIGANTS

Currently, the most popular irrigants are NaOCl sodium hypochlorite. It has excellent antibacterial activity and can dissolve organic tissues. The effectiveness of sodium hypochlorite is dependent on the concentration and time of exposure with the tissues and organisms. Higher concentration of sodium hypochlorite could dissolve the tissues faster than that of lower concentration. However, higher the concentration, the more severe the potential reaction if it is entered beyond the periapical tissue. This leads to complications such as pain, swelling, and sodium hypochlorite accident. This accidental extrusion of sodium hypochlorite into the periapical tissues may result in tissue damage.

During root canal irrigation, when using instruments, a layer of sludge is formed from the dentin walls. This material is called as smear layer. It contains both organic and inorganic components. It includes superficial, loose layer, and deep adherent layer. Complete removal of smear layer might expose the dentinal tubules to the passage of microorganisms into the dentine tissue and also failure to remove the smear layer allow the bacteria to settle in the canal system untouched and impair the process of root canal filling. Removal of the smear layer has been achieved by the irrigation of root canal system with NaOCl throughout the procedure and preventing accumulation of debris in the root canal. A final irrigation with a specific concentration of ethylenediaminetetraacetic acid (EDTA), a chelating agent, is used for the removal of inorganic components.

EDTA has low antibacterial effect. EDTA can destroy bacteria when exposed to it for longer period. It is an effective chelating agent. It dissolves the inorganic compounds in the root canal. By removing the smear layer and inorganic components, it helps to eliminate the bacteria.

10% citric acid is more effective in removing the smear layer than the ultrasound techniques. In a study, it has been reported that the 10% citric acid is more powerful in removing the dentin layers than the

EDTA. Smear should be removed to be able to gain access by the irrigants into the deeper root structures to have effective cleansing. Citric acid and EDTA have weak antimicrobial property.

Hydrogen peroxide is also biocide. It is used in sterilization of instruments and disinfection. It has been effective against the Gram-positive bacteria. It has very good cleansing property and hence used in endodontic treatment. It is used to remove the blood and tissue remnants. It has low effectiveness as an irrigant.

Chlorhexidine digluconate (CHX) is used as a disinfectant. It has high antimicrobial effect. It has no smell and is not irritating like NaOCl. However, it lacks the ability to dissolve the tissue remnants accumulated in the root canal. It is also used in antiseptic products as it has anti-infective activity. CHX is more effective, especially against the Gram-positive, than the Gram-negative effect organisms. CHX is not effective against the viruses.

CHALLENGES OF IRRIGATION

Smear layer removal is the primary concern. However, when specified suitable irrigants are used, it is predictable in removing the smear layer. The use of hypochlorite during instrumentation has become popular, but due to accidents and complications, it has been deployed as an unusable and unreliable irrigant. Moreover, smear layer is formed in the areas contacted by the instruments, and hence, incomplete removal of smear occurs when all the areas are not cleared by the irrigants.

The dentin erosion must be prevented during endodontic treatment so that the physical procedures and chemical treatments could not weaken the dentin and root canal. Dentin erosion is harmful and must be avoided. In a study, it was reported that long exposure to the chemical irrigants can cause damage to the dentin and reduce the flexural and elastic properties of the dentin. However, short time exposure to the hypochlorite also causes damage and allows the agent to enter deep into the dentin layers.

It is somehow easy to remove the debris and smear in the instrumented areas. The challenge is to remove the necrotic tissue, debris, and biofilms from the uninstrumented regions. These regions are completely relied on the effect of the chemical irrigants. NaOCl has been the reliable irrigants in achieving the results despite its consequences. In a study, it had been found that the untouched areas like the anastomoses were filled with the debris during instrumentation. Hence, clearing these areas has been a challenge in endodontics.

Biofilm can be removed by mechanical instruments and by the irrigants, especially sodium hypochlorite, which can dissolve the biofilm. The ultrasonic waves can also be used to detach the biofilm and then cleared away by the irrigants or instruments. CHX can destroy the bacteria present in biofilms. As CHX lacks dissolving property, the microbial biofilm should be removed mechanically. The presence of any debris, biomass, and organic matter in the root canal can have a potential effect on the integrity of the root sealing.

DIFFERENT MODES OF IRRIGATION BASED ON PRESSURE TECHNIQUES

Positive Pressure Irrigation

The delivery of the irrigants, using the syringe or needle, into the root canal conventionally uses the positive pressure application. This mode of delivery has many limitations. The irrigants cannot be delivered further than 1–2 mm beyond the tip of the needle, and hence, effectiveness can be acquired only when the needle is placed 1–2 mm from the working length. The positive pressure exerted near the apical foramen can cause a potential risk of extrusion of irrigants beyond the apex into the periapical tissues. This would lead to serious complications commonly named as sodium hypochlorite accident.

Sonic and Passive Ultrasonic Irrigation

These techniques are developed to agitate and cause streaming movements of the irrigant solutions to increase the efficacy of its action. Sonic irrigation functions at low frequency and high amplitude and produces small shear stress. Passive ultrasonic irrigation is smooth in nature and vibrates at an ultrasonic frequency. The vibration of the files causes acoustic streaming. Hence, it makes the passive ultrasonic irrigation more effective. However, this technique may be ineffective in curved canals.

Negative Pressure Irrigation

The limitation shown in the other irrigation techniques led to the discovery of the negative pressure irrigation technique. This technique uses the negative pressure to deliver the irrigants into the specific areas and to clear away the debris from the root canal. The small cannula which applies the negative pressure can reach the full working length. The root canal is continuously irrigated and the continuous flow of irrigants could cause the irrigants to reach all the areas, and simultaneously, the microcannulae aspirate the irrigants to remove the debris and tissue remnants along with the irrigants solution. This technique requires the enlargement of canals. Hence, it is more effective in straight canals and limited in curved canals.

Comparison of the Pressure Techniques

Chemical irrigants and physical devices are being applied to achieve the effective irrigation. However, the ability of the root canal irrigation system is very much dependent on the effectiveness of irrigants and the mechanical function of the irrigation technique. Hence, effective cleaning of roots could only be achieved by well-crafted mechanical device and the ability of the chemical agents. Conventional positive apical needle irrigation has shown difficulties to improve the delivery of chemical solution into the apical third of the root canal. This has been proved by Nair *et al.*[6] who showed that biofilms were found in mandibular molars even after the procedure of positive pressure irrigation. Mechanical instrumentation of the apical third becomes challenging due to the presence of fins, lateral canals, and apical deltas.[7,8] The irrigants injected into the root canal usually destroy the biofilm in laboratory studies. Hence, it appears that debris formed during instrumentation gets compacted against the apical anatomy, fins, and isthmus and made the irrigants hard to reach the apical-most part of the root canal, especially when positive irrigation is carried out. To avoid such consequences, the need for the irrigation technique that could avoid the accumulation of debris or remove the debris accumulated developed. Hence, the negative pressure irrigation techniques which suck the debris from the root canal are created. Figure 1 shows the difference in technique in both negative and positive pressure irrigations.

For a device to be effective in delivering the irrigant solution effectively and satisfy the goals of endodontics, it should be able to reach the apical region of the root canal. It should be able to create a current force along the walls of the root and has the ability to remove debris, tissue remnants, and bacterial contaminants. Currently, the irrigant which could achieve these functions is sodium hypochlorite. NaOCl reacting with organic tissues in the root canal forms water by hydrolysis and release ammonia and CO_2 as by-products. A gas column develops at the apical third of the root canal which is called as apical vapor lock. The difficulty faced by the clinicians is to deliver the irrigant solution to reach the apical third safely and effectively and break the apical vapor lock and to allow the exchange of irrigants constantly without the apical extrusion.

Apical Negative Pressure Irrigation System

Pressure is defined as force per unit area. In the endodontic treatment, when the irrigant is delivered into the root canal, the pressure is exerted on the walls. Negative pressure occurs when the enclosed space has lower pressure than the surrounding space. It acts like the vacuum cleaner. The EndoVac system was developed to safely and predictably deliver the irrigant to the apical regions of the root canal. Hence, it will lead to a better penetration of the irrigant solution deep into the complex anatomies of the root canal structures. These anatomical complexities make the irrigation more difficult.

The EndoVac System

The EndoVac system [Figure 2] uses the suction technique to clear out the debris and promote the flow of the irrigant solution to reach the apical third of the root canal.[9] This suction pressure creates a movement of the chemical solutions placed in the chamber of the device. The chamber is located in between the master delivery tip and the end of the canal where the tip of the microcannulae is placed.

The EndoVac system uses two steps to remove the debris. The first step involves a macrocannula of 0.55-mm diameter placed in the middle third to eliminate gross debris and pulp remains. The second step includes a microcannula of 0.32-mm diameter used for the full working length to remove the minute debris.[10] Therefore, appropriate apical enlargement to a minimum of a size 0.35 file must be created to ensure that the microcannula tip (0.32 mm) reaches the apical tip. Figure 3a and b show the macro-and micro–cannulae, respectively.

EndoVac system has the advantage of eliminating the debris formed from the instrumentation of shaping the root canals and also the necrotic remains using a safe delivery of the chemical irrigants to the full

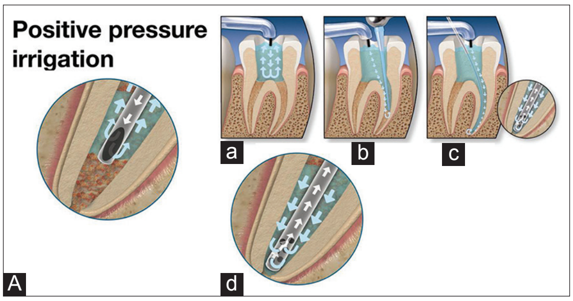

Figure 1: (A) The positive pressure irrigation needle is placed short of the working canal length due to the risk of extrusion beyond the apical region. (B) Negative pressure irrigation. (a) Master delivery tip filling the canal with irrigant. (b) Macro cannulae allowing the solution to reach the full working length. (c) Micro cannulae draws the solution to reach the critical apical region of root canal. (d) Micro cannulae has side vents which are helpful in eliminating the debris by suction method

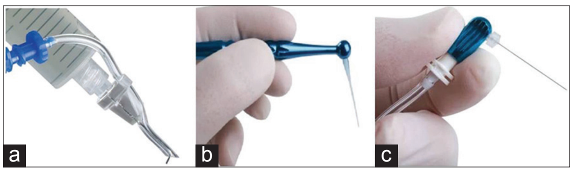

Figure 2: EndoVac system. (a) Master delivery tip, (b) macro cannulae, (c) micro cannulae

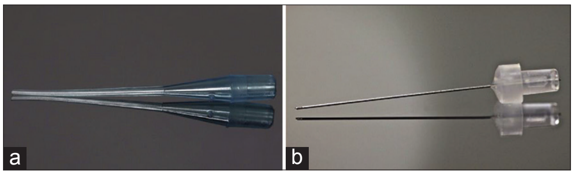

Figure 3: (a) Macro cannulae. (b) Micro cannulae

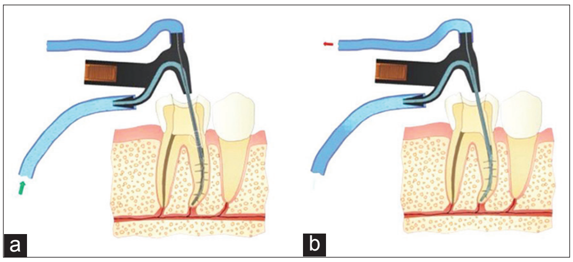

Figure 4: Mode of operation in apical negative-pressure irrigation. (a) Intial flow of irrigants. (b) Simultaneous flow and suction of irrigation

working length in the root canal without the risk of apical extrusion.[11,12] Many researchers have reported the advantages in EndoVac system when compared to the other irrigation techniques. The advantages in EndoVac include free from risks such as the extrusion of apex and improved cleaning quality.[13-16] The researches conducted by various authors in their report showed that the histological studies showed the advantages of the EndoVac system which improved the quality of cleansing in the apical one third.[1,12,17] In a study by Baumgartner and Nielsen,[1] using teeth extracted with vital pulps, it was shown that EndoVac resulted in improved cleaning efficacy at 1 mm from working length when compared to conventional irrigation. From these studies, the authors showed that the EndoVac system delivered a greater volume of irrigants which was 3 times more when compared to the conventional needle irrigation. These results were confirmed in further studies, where the EndoVac system exhibited superior ability to eliminate the debris from the apical third of vital root canal.

Apical Negative Pressure Free from Extrusion of the Irrigants

Irrigants are helpful in achieving the goal of cleanliness.[4,18] However, certain irrigants could be extruded into the periapical tissues, which would lead to unwanted complications such as inflammation and hematoma, and sometimes, necrosis could also occur.[18-20] Hence, it is necessary to reduce the risks associated with root canal irrigation that would benefit the patient more.[13] In a study, Himel and Desai,[13] Brown,[21] Montgomery and Myers,[22] and Roy and Laurence[23] reported that the positive pressure irrigation could result in extrusion of the apical root canal. However, Desai and Himel,[13] Fukumoto,[24] and Mitchell[14] demonstrated that negative pressure irrigation could be reducing the periapical extrusion. Desai and Himel researched the EndoActivator, Ultrasonic needle irrigation, and RinsEndo. In EndoActivator, the volume of extruded irrigants was very less comparing ultrasonic needle irrigation and RinsEndo. Hence, concerning extrusion negative pressure irrigation is comparatively safe.

Apical negative pressure irrigation irrigated the root canal system effectively to the fullest of the working length.[25] This is due to the design of the microcannulae, which avoids the vapor lock effect. However, the negative pressure irrigation could not completely activate the irrigants in the non-instrumented areas.

Irrigation of Curved Root Canals

Root canals are curved structures,[26] which make them more difficult in accessing and cleaning. This difficulty is due to the contact between the device needles and canal walls. Hence, bending the instrument to follow the canal structure becomes a necessary; however, it could compromise the irrigation greatly.[27] Rodig *et al.*[28] and Amato *et al.*[29] reported that the curvature reduced the cleaning efficiency of several irrigation techniques. However, continuous ultrasonic irrigation and passive ultrasonic irrigation reaches the working length in curved canals. This is due to the sufficient force exerted at the tip of the instrument to overcome the vapor lock effect. As a result, both exhibit an increase in penetration of the irrigants into the lateral canal and apical third of the canal.[30-33] Figure 4[34] shows the mode of operation of CANUI - A new concept of irrigation.

In a study, Abarajithan *et al.*[35] reported that apical negative pressure irrigation and positive pressure irrigation were equally effective in eliminating the smear layer from the coronal amped middle third of the root canals, while in the apical third, the EndoVac system performed significantly better than the needle irrigation. Their results are ordinary considering their usage of large-sized apical areas to improve the irrigant flow to the root canals. The difference in smear layer removal at all levels was significant and better than the positive irrigation. The reason behind this finding is due to failure of positive irrigation to avoid vapor lock effect in the closed canal system.[36]

Several studies have compared the effectiveness of both positive and negative apical pressure irrigation techniques.[16,37] However, no differences were found between these two treatment techniques. This could be explained on the basis of the usage of single-rooted teeth on these studies which were lacking the complex anatomy of the apical root canal. Furthermore, single-rooted teeth could be cleaned easily than the posteriorly positioned teeth. This would certainly explain the absence of difference in efficacy between the positive and negative pressure techniques in clinical settings. The challenge in endodontic treatment is the cleaning of complex regions in root canals. Considering this, the negative apical pressure has a slight advantage over the conventional methods in *in vivo* researches.

Although negative pressure irrigation would improve the irrigant volumes, contact with the root canal walls, mainly in the uninstrumented areas, which would increase the disinfection and debridement, it is still the questionable debate about the exposure and volume of irrigants in improving the effectiveness of cleansing in the root canal.

CONCLUSION

This review has shown some lights on the EndoVac system which has a slight upper hand over the conventional positive method. Hence, the negative apical pressure system's improved cleaning ability would result in remarkable improvements in the treatment of complex regions in the root canal. However, many studies are needed to be done to achieve this in real clinical settings. Since the introduction of the negative pressure technology, many studies have been carried out to modify the technique to attain the effective irrigation.

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