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Newer Irrigation Systems in Endodontics: A Literature Review

Medical Science

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ABSTRACT

The aim of endodontic therapy is the debridement of all vital or necrotic tissue, microorganisms, and their products from the root canal system. This may be accomplished by chemomechanical debridement of root canal. However, irregular and oval canal cross-sections, accessory canals, isthmuses, fins, curves and apical delta make chemomechanical debridement difficult. Thus irrigation of root canal system becomes very essential. Various irrigants and irrigation systems have been introduced. This review article features the newer advances in irrigation systems for better debridement of complex root canal system.

INTRODUCTION

Endodontic treatment is a predictable procedure with high success rates. The root canal is working area and root canal anatomy defines the complexity of it. The success of endodontic treatment depends on the removal of all vital or necrotic tissue, eradication of microbes and byproducts from the canal to prevent re-infection. The quality of canal cleanliness depends on the design of cutting blade of rotary instruments in addition to complexity of the canal. Peters et al. on microCT scans of canals found that, regardless of the instrumentation technique, 35% or more of root canal surfaces remained un-instrumented. [1] The microorganisms present in the root canal even after adequate treatment invade the anatomic irregularities of the system and can re-infect. Enterococcus faecalis has frequently been isolated from root canals in cases of failed root canal treatments[2] as it can penetrate deep into dentinal tubules, being almost impossible to remove through mechanical instrumentation. Therefore, the use of chemical agents during instrumentation to is important for the clinical success.[3] Irrigation dynamics play an important role[4]. Irrigating solutions act mainly as lubricant and cleaning agent removing microorganisms, organic and inorganic particles, ensuring elimination of contaminated dentin and permeability of the canal. However, there is currently no unique irrigant that meets all the requirements for an optimal irrigating solution,[5] even when they are used with a lower pH, increased temperature or added surfactants to increase their wetting efficacy.[6] But with the introduction of modern irrigation techniques, success rates of up to 98% are being achieved. This review article highlights the newer irrigation systems and their mechanism of action. For this review article we searched for all English language articles using keywords irrigation in endodontics' and 'irrigation for root canal' on Google and Google Scholar and mainly the systemic reviews were included.

A large number of substances have been used as root canal irrigants, including acids (citric and phosphoric), chelating agents (EDTA), proteolytic enzymes, alkaline solutions (sodium hypochlorite, sodium hydroxide, urea and potassium hydroxide), oxidative agents (hydrogen peroxide and Gly-Oxide), local anaesthetic solutions and normal saline. As none of the above achieves total irrigation from anatomical variations of the canals, newer irrigation techniques have been introduced to increase effectiveness. The irrigant delivery and agitation systems for root canal irrigation might be divided into two broad categories, manual agitation techniques and machine assisted agitation devices.[7] Conventional syringes with various needle's diameter, manual brushes and fitted gutta percha cones come under a manual method. Other than conventional irrigation techniques, different techniques and devices have been introduced including Gaseous ozone, Electrochemically activated solutions, Self Adjusting File, EndoActivator, Ultrasonic irrigation, Photo activated irrigation, EndoVac and Endo Irrigator Plus.

Manual Dynamic Irrigation

Manual dynamic irrigation describes the irrigation technique which involves repeated insertion of iirigant and a well fitting gutta-percha cone to working length of a previously shaped canal. The gutta-percha cone is applied in short, gentle strokes to hydro dynamically displace and activate an irrigant.[8] It is a cost effective technique for irrigation.

Mechanical Agitation Techniques

I. Rotary Brush:- A rotary handpiece–attached microbrush has been used. The brush includes a shaft and a tapered brush section. It has multiple bristles extending radially from a central wire core. During the debridement phase, the microbrush rotates at about 300 rpm, causing the bristles to deform into the irregularities of the preparation. This helps to displace residual debris out of the canal in a coronal direction. However, this product has not been commercially available. Example: Ruddle brush

II. Canal Brush: This highly flexible micro brush has been made entirely from polypropylene and might be used manually with a rotary action. Weise et al., showed that debris was effectively removed from simulated canal extensions and irregularities with the use of the small and flexible Canal Brush with an irrigant.[9]

Max-I-Probe:-

Max-i-probe is a modified regular manual irrigation needles with a well-rounded, close tip and side-port venting. This needle is available from 21 to 30 gauges. It has the luer lock connector. As per the manufacturer, the rounded tip prevents the risk of perforating the apex and the dispersal of the irrigating solution through the side-port creates a unique upward turbulent motion, which thoroughly irrigates the root canal but prevents solution and debris from being transported through the periapical foramen.[10]

Navi Tip Fx:-

NaviTip Fx [Figure 1] is a 30-gauge irrigation needle covered with a brush. It was introduced commercially by Ultradent company. Brush is incorporated for debridement of the canal walls and agitation of root canal irrigant which was helpful in im-

proved cleanliness of coronal third when compared to brushless NaviTip needle.[10] The drawback is NaviTip FX brush bristles may dislodge inside the canal irregularities and because of its radiolucent nature it is very difficult to identify radiographically or even with the use of a surgical microscope.[7]

The manual needle irrigation systems allow good control of needle depth and the volume of irrigant that is flushed through the canal. However, the mechanical flushing action created by conventional hand-held syringe needle irrigation is relatively weak as the inaccessible canal extensions and irregularities are likely to harbour debris and bacteria, thereby making thorough canal debridement difficult.[10] These drawbacks of conventional hand held syringe needle irrigation lead to the development of machine assisted irrigation systems.

Continuous Irrigation During Rotary Irrigation:-
The Quantec-E irrigation system (SybronEndo) is a self-contained fluid delivery unit. It is attached to the Quantec-E Endo System and uses a pump console, two irrigation reservoirs and tubing. This provides continuous irrigation during rotary instrumentation.

Electrochemically Activated Solutions :-
Electrochemically Activated (ECA) solutions are produced from tap water and low concentrated salt solutions. The ECA technology developed by Russian scientists is based on the Principle of transferring liquids into a metastable state via an electrochemical unipolar (anode or cathode) action through the use of an element/reactor ("Flow-through Electrolytic Module" or FEM). The FEM is made up of an anode, a solid titanium cylinder with a special coating that fits coaxially inside the cathode. A cathode is a hollow cylinder also made from titanium with another special coating. A ceramic membrane separates them. The FEM can produce bactericidal, sporicidal and odourless solutions which are safe to human tissue, and noncorrosive for most metal surfaces.[10,11] Freshly prepared superoxidized solution is highly active against all microorganisms giving a 99.999% or greater reduction in two minutes or less and can be used as a potent microbiocidal agent. The cleaning effectiveness of root canal irrigation with ECA solution is similar to NaOCl in terms of debris removal but more than NaOCl in smear layer removal.

Thus ECA can be a potential root canal irrigant due to its ease of removal of debris and smear layer, nontoxic nature and efficiency in apical one third of canal.[11]

Ozonated Water:-
Ozone is a very powerful bactericide with oxidizing any biological entity that can kill microorganisms effectively. At low concentration of 0.1 ppm, it can inactivate bacterial cells including their spores. In water, ozone dissolves rapidly and dissociates more quickly. Various delivery systems available for endodontic irrigation like Neo Ozone Water-S unit, HealOzone (Kavo) unit, the OzoTop unit.

Nagayoshi et al. found almost comparable killing ability of ozonated water and 2.5% of sodium hypochlorite when the specimen was irrigated with sonication.[10] Combined use of 1.31% NaOCI and Ozonated water have increased antibacterial effect compared to 1.31% NaOCI or ozonated water alone.[12] In a study by Cardoso, it was found that ozonated water was effective against *Candida albicans* and *Enterococcus faecalis but* it was not able to neutralize *E. coli* and lipopolysacharides (LPSs) inside root canals and the remaining LPS may have biological consequences such as apical periodontitis.[13] Although ozonated water is a powerful antimicrobial agent , further studies and modifications in ozonated water are required to be used as a root canal irrigant.

Ultrasonic Irrigation:-
A needle-holding adapter to an ultrasonic handpiece has been developed by Nusstein.[10] A 25-gauge irrigation needle is used rather than an endosonic file. Ultrasonic activation is performed at the maximum power without causing needle breakage. An irrigant is delivered from tubing under a continues flow, connected via a Luer-lok to an irrigation-delivering syringe.

There are two types of ultrasonic irrigation. 1) combination of simultaneous ultrasonic instrumentation and irrigation (UI). 2) Irrigation without simultaneous instrumentation which is referred to as passive ultrasonic irrigation (PUI).[14] When ultrasonic activated files are used along with irrigation, canal deviations, apical zips and radicular perforations can be occur, especially in curved canals. It therefore has been almost discarded in the clinical practice.

The term PUI was first used by Weller et al. in 1980. Passive ultrasonic irrigation is more advantageous as it reduces the potential for creating aberrant shapes in the root canal system. After activation, energy is transmitted from a file or smooth oscillating wire to the irrigant by means of ultrasonic waves. This causes two types of physical phenomena: Acoustic stream and cavitation. The acoustic stream is a rapid movement of the fluid in a circular or vortex shape around the vibrating file/wire. Cavitation is the creation of steam bubbles or the expansion, contraction and/or distortion of preexisting bubbles in a liquid. Use of the combination of NaOCl and PUI improves the exchange of substances in the canal, eliminates smear layer and thereby helps in achieving greater cleaning effect.[15] In comparison to sonic irrigation, ultrasonic irrigation has proved to be more powerful and able to eliminate more debris, and so it is claimed that passive ultrasonic irrigation is significantly more efficient than sonic activation.[14]

Photon-Activated Disinfection:-
The use of photodynamic therapy (PDT) for the inactivation of microorganisms was first shown by Oscar Raab. The principle on which PDT is based on is that non toxic photosensitizers can be localized in certain tissues and can be activated by light of the appropriate wavelength to generate singlet oxygen and free radicals that are cytotoxic to cells of the target tissue.[16]

Methylene blue (MB) is used as a photosensitizer in PDT for targeting various gram-positive and gram-negative oral bacteria. MB along with red light (665 nm) can also be used which has exhibited up to 97% reduction of bacterial viability.[4] Other than red light, tolonium chloride has been also used as a photosensitizing agent. It is applied to the infected area and left for a short period so that it can bind to the cellular membrane of bacteria. On appropriate laser activation (e.g.653 nm) it will rupture. The laser emits a maximum of only 100mW energy so heat produced will not enough to harm adjacent tissues. Moreover, tolonium chloride dye is biocompatible and does not stain dental tissue. FotoSan is the PAD device recently introduced by CMS Dental. Thus, PAD can be a useful tool to conventional root canal treatment.

Self Adjusting File- The VATEA System [Figure 2]:-
The SAF is the first file that does not have a solid metal shaft. The file is a hollow tube with its walls are made from a thin nickel titanium lattice [Figure 3] with a rough outer surface. The VATEA system is an irrigation device and forms an integral part of SAF. The VATEA system is a self-contained, peristaltic pump. It is a built in irrigant reservoir of 500 mL operated using a foot switch and powered by a rechargeable battery. The SAF file has a freely rotating hub connected to a polyethylene tube. Irrigation solution is pumped from the VATEA's reservoir to this tube which allows the flow of the irrigant through the hollow file to the root canal. The flow rate at which the irrigant can be deliv-

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ered into the tube ranges from 1-10 mL per minute, with recommended setting of 4 mL per minute.

The SAF System is based on a no pressure irrigation system that is active throughout the instrumentation process.[17] Once the irrigant enters the SAF, due to the lattice structure of the file, any pressure that may have existed in the delivery tube disappears. The vibrations of the file along with the pecking motion result in the continuous mixing of the irrigant present in the root canal with fresh, fully active irrigant. The SAF system also provides the scrubbing effect which is not possible with PUI or EndoVac system, is a more effective way to clean surfaces of materials that are attached to them. Highly effective cleaning of the canal walls can be achieved by combined scrubbing with the continuous flow of fresh, fully chemically active sodium hypochlorite.[18] SAF can be more effective for irrigating curved canals, oval canals and c-shaped canals.[19]

The Endo Activator System [Figure 4]:-
The EndoActivator System *(Dentsply Tulsa Dental Specialties)* is recently introduced sonically driven canal irrigation system. It consists of a cordless, contra- angled, three-speed, battery-operated handpiece and 3 types of disposable polymer tips of different sizes. The tips are made from a medical-grade polymer and are claimed to be strong and flexible and do not break easily. They are color-coded as yellow, red, and blue, closely corresponding to sizes 15/02, 25/04, and 35/04, respectively. They are smooth and do not cut dentin. Vibrating the tip at 10,000 cycles per minute (cpm) along with moving the tip up and down in short vertical strokes, produces a powerful hydrodynamic phenomenon. This hydrodynamic action can improve the penetration, circulation, and flow of irrigant into the more inaccessible regions of the root canal system.[20] Studies have shown that agitating a solution is a method to more effectively remove calcium hydroxide from a prepared canal.[21] It is also helpful in delivering mineral trioxide aggregate *(MTA, Dentsply Tulsa Dental Specialties)* into blunderbuss canals, in straight or curved canals, and in the retreatment situation to break up and dislodge remnants of obturation materials.

The EndoActivator System has shown effective cleaning of debris from lateral canals, removal of the smear layer, and dislodgement of clumps of simulated biofilm within the curved canals.[22]

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

I. The Rinsendo Irrigation System (Rinsendo, Co. Duerr- Dental, Bittigheim-Bissingen, Germany)

This system irrigates the canal by using pressure-suction technology. It includes a handpiece, a cannula with a 7 mm-long exit aperture, and a syringe carrying irrigant.[10] The handpiece has an irrigation speed of 6.2 ml/min. From an attached syringe, 65 mL of a rinsing solution oscillating at a frequency of 1.6 Hz is transported to the canal via an adapted cannula. Used solution and air are recollected from the root canal and automatically merged with fresh rinsing solution during suction phase. The pressure-suction cycles continue for approximately 100 times per minute.[7] The pulsating nature of the fluid flow, helps to rinse the apical third of the canal , with the cannula restricted to the coronal third of the root canal. However it is found to be less effective in removing the stained collagen from root canal walls and has high risk of apical extrusion of irrigant.[10]

II. The Endovac System:-
Designed by Dr. G. John Schoeffel, the EndoVac irrigation system (Discus Dental, Culver City, Calif.) was developed to irrigate and remove debris to the apical constricture without forcing solution out the apex into the periapical tissue. It contains three basic components: 1)a Hi-Vac adapter assembly that connects to the high volume evacuation hose in the dental operatory at one end and has a "T" connector at the other end [Figure 5] which permits a Master Delivery irrigation- suction tip (MDT) with a disposable syringe [Figure 6] filled with irrigation solution, 2)the Macrocannula,[Figure 7] and 3)the Microcannula [Figure 8]. The MDT delivers irrigant. It is of 0.55 mm in diameter, an internal diameter of 0.35 mm, and a 0.02 taper, also used for suction of irrigants up to the middle part of the canal. The Macrocannula is utilized to remove coarse debris after instrumentation and is used in combination with the Master Delivery Tip. The Microcannula has a closed end with external diameter of 0.32 mm made up of stainless steel and has 12 microscopic holes arranged in 4 rows of 3 holes, laterally positioned at the apical 1 mm of the cannula. Each hole is 0.1 mm in diameter, with in between distance of 0.2 mm and the first one in the row is located 0.37 mm from the tip of the microcannula. The cannula in the canal exerts negative pressure which pulls the irrigant down the canal to the tip of the cannula, into the cannula, and out through the suction hose. Thus, a fresh irrigant is being delivered continuously by negative pressure to working length and apical negative pressure helps to overcome the issue of apical vapor lock.[23]

The EndoVac system shows better microbial control and significantly better removal of debris at 1 mm apical level than needle and other traditional irrigation.[10] In comparision with other systems like passive ultrasonic, F File, the Manual Dynamic Max-I-Probe, the Pressure Ultrasonic, and the EndoActivator, the EndoVac system is capable of cleaning 100% of the isthmus area.[10,24] However, The manufacturer's instructions must be followed for correct use of the system and mainly the Master Delivery Tip.

Endo Irrigator Plus (K Dent Dental System) [Figure 9-13]:-
This product is invented and designed by Dr Mandar Pimprikar. It is based on ACWIS concept, i.e. activated continuous warm irrigation and evacuation system. Trials done under electronic microscope found that this device really helps penetration of Sodium Hypochlorite Solution into the lateral and accessories canals. Strong vacuum evacuation system insures that Sodium Hypochlorite doesn't reach the periapical region so it does not harm or damage the peri-apical tissues. This device creates positive and negative pressure inside the canal. This gives a perfect cleaning and disinfection of root canal assisted by negative and positive pressure with warm Sodium hypochlorite. In this unit the Sodium hypochlorite is warmed upto 45°. Positive pressure irrigation with warm hypochlorite cleans and disinfect upto middle 1/3rd, removes all macro debris and negative pressure irrigation with warm hypochlorite cleans and disinfect upto apical 1/3rd, removes all micro and nano debris. According to the manufacturers due to its powerful suction ability not even a single drop of Sodium Hypochlorite solution comes out of the canal (even if working in maxillary molars or if there is wide/ open apex)

Figure 1:- Navi Tip Fx

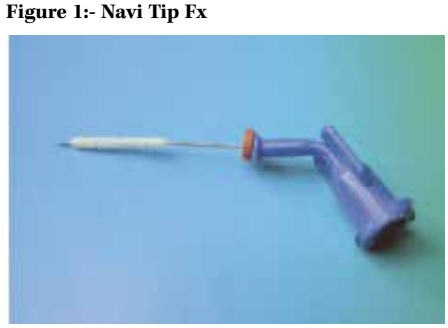

Figure 2:- SAF- The Vatea System

Figure 3:- a)SAF and b) Lattice

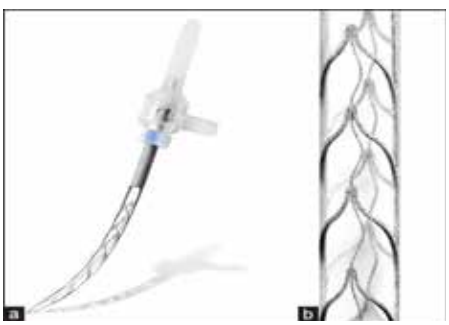

Figure 4:- Endo Activator System

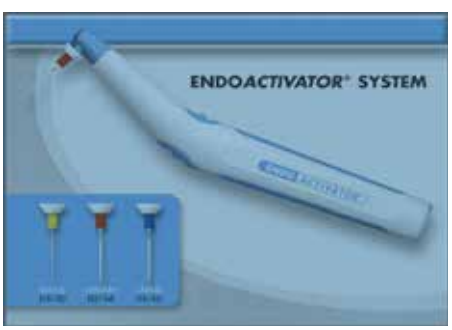

Figure 5:- EndoVac system- Hi Vac assembly

Figure 6:- EndoVac system- Master Delivery Tip. Delivery Tip

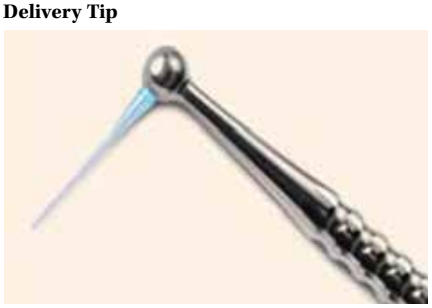

Figure 7:- EndoVac system- Macrocannula

Figure 8:- EndoVac system- Microcannula

Figure 9:- Endo Irrigator Plus- Front View.

Figure 10:- Endo Irrigator Plus- Back View

Figure 11:- Endo Irrigator Plus Irrigation and Evacuation Tip

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Figure 12:- Endo Irrigator Plus- Negative Pressure Tip.

Figure 13:- Endo Irrigator Plus- Microholes.

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