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Comparative analysis of the effectiveness of modern irrigants activation techniques in the process of mechanical root canal system treatment (Literature review)

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Abstract.

Development of apical periodontitis is the most common complication of unsuccessful endodontic treatment. Cleaning the root canal system is a crucial stage and the main factor for a successful endodontic protocol. Inability to remove debris from inaccessible branches of the root canal system, especially from the apical region, leads to and increases the risk of secondary infection. Selection of the optimal method for activating irrigants remains a current issue. According to the results of several studies, none of the individual irrigation activation techniques allows achieving ideal cleanliness in the root canal, but the use of laser, sonic, multisonic, and ultrasonic activation significantly improves the quality of cleaning and provides a prolonged antimicrobial effect by enhancing the diffusion of intracanal antiseptics, their hydrolytic and antibacterial effectiveness, which will eventually ensure maximum adhesion of filling materials. This, in turn, indicates the absence of a unified protocol that would provide stable irrigation efficiency and long-term

results in endodontic treatment. The use of a protocol with combined activation of irrigants remains an open question among clinicians and scientists.

Keywords:
root canal
irrigation
activation
Sodium hypochlorite
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debris
ultrasonic
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XP-Endo Finisher

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Activation of irrigants is one of the key stages in the medication-based treatment of root canals, which involves achieving the solution's penetration into all areas of the root canal and enhancing its antimicrobial activity. Therefore, various methods of irrigant activation have been developed to improve their effectiveness. Sodium hypochlorite (NaOCl) is the most commonly used irrigant, which possesses proteolytic properties towards pulp tissue, exhibits excellent antimicrobial properties, and affects biofilm. However, it poorly removes any accumulated remnants of hard tissues. Therefore, it is used in combination with demineralizing/chelating solutions to remove the smearing layer and dentin debris, typically using ethylenediaminetetraacetic acid (EDTA) [1-3].

Let's consider possible methods of sodium hypochlorite activation:

- Manual activation is divided into irrigation delivery with a syringe and manual dynamic activation. Manual dynamic activation (MDA) is a method based on vertical movements of the irrigation needle or a gutta-percha cone, which can facilitate the penetration of the irrigant to the working length by creating a hydrodynamic effect. However, practical studies question the effectiveness of this activation method due to its low efficiency in cleaning canal curvatures, fins, and delta-shaped ramifications [4]. Thus, despite its accessibility, this method is the least effective.

- Machine-enhanced irrigation is based on the use of brushes in combination with an angled tip, which promotes rapid mixing of the irrigant and its activation. This activation method reaches inaccessible areas in root canals and provides better tissue and debris removal compared to conventional instrumentation without any activation. However, there is a relationship between the brush size and the ability to reach the working length, as well as the risk of pressing debris, especially in the apical part of the root canal. Research also indicates the high effectiveness of this activation method in removing the smear layer [5].

- Ultrasonic activation is a method that involves applying ultrasonic vibrations in the range of 25-32 kHz to activate the irrigant. This technique improves chemical cleaning by creating circulating acoustic microflows, the

movement of the irrigant around the vibrating file, and the formation of acoustic cavitation, which promotes the formation and flow of bubbles. This power facilitates the flow of the irrigant into remote areas of the root canal system [6]. Generally, two principles of ultrasonic usage have been researched. The first one is ultrasonic instrumentation, which combines irrigation and instrumentation steps. However, this method is not relevant due to the inability to control the preparation of root canal dentin with ultrasonic files, which can lead to changes in the original canal shape and an increased risk of strip perforations. The second principle is passive ultrasonic activation, which activates the irrigant using ultrasound without simultaneous instrumentation, although this term may be considered outdated because the basis of passive activation was the concept of the instrument freely moving within the canal without any contact with dentin [7]. With this technique, vibrations are transmitted from the file to the irrigant inside the root canal to generate an acoustic flow and solution cavitation. The instrument requires sufficient space for unobstructed vibrations, so activation occurs only after prior chemomechanical preparation, best demonstrated by cleaning at vibrations around 50-80 μm and with an apical enlargement to a size of 30-35 according to ISO [6]. However, the main drawback of ultrasonic activation is its poorer performance in canal curvatures due to the instrument.

– Sonic activation is based on sound vibrations in the range of 1000-6000 Hz to agitate the irrigant. Studies failed to prove the advantages of Endoactivator (Dentsply Sirona, Charlotte, NC) in cleaning the canals, isthmuses, and fins over syringe irrigation [8]. Additionally, Endoactivator was less effective compared to ultrasonic activation with the same irrigation time. In contrast, EDDY (VDW, Munich, Germany) demonstrates cleaning efficiency on par with ultrasonic activation [9]. Other studies indicate similar effectiveness between EDDY and syringe irrigation in terms of antibacterial aspects [10] and debris removal from isthmuses [11]. This is due to the large size of the instrument, which displaces most of the solution outward when entering the canal, and excessive power does not allow for minimal exposure to the irrigant. In comparison to sonic and ultrasonic activation methods,

research shows a better effect of the ultrasonic method in removing pulp remnants, although sonic devices work better in all canal segments, particularly in areas with curvatures where ultrasonic activation methods perform less effectively.

- Laser activation is based on optical cavitation achieved by creating and collapsing micro-explosions of bubbles, stimulating the penetration of the irrigant deep into the canal with subsequent heating and activation of the solution [12]. This effectiveness is provided by the photon-induced photoacoustic streaming (PIPS), which has a tip that is immersed in the irrigant in the pulp chamber, while consuming very little energy and causing minimal temperature increase in the tooth's hard tissues. This allows for effective activation of the irrigant throughout the entire length of the root canal, including curved areas, without unwanted preparation of the canal walls [13]. It has been proven that laser activation disrupts Candida albicans and highly resistant E. faecalis, in addition to dissolving the smear layer and dentin debris [14]. Some studies claim that this method is more effective than ultrasonic activation, especially in the curvature areas of root canals [15]. However, there are also studies indicating a statistically insignificant difference in the effectiveness of irrigation activators [16]. Laser activation is an effective method of activating the irrigant but does not guarantee a perfectly executed irrigation of the root system. The application of this method, as well as the ones described above, is based on a clinical case, hence requiring further verification, investigation, and the competence of the dentist to achieve the desired result.

- Multisonic activation is the most advanced method in chemical root canal irrigation. It is based on the creation of microscopic bubbles formed by acoustic waves at different frequencies to improve the penetration of irrigants into the smallest spaces of the root system and inside the dentinal tubules, enhancing the chemical action of the irrigant [17]. GentleWave (Sonendo, Laguna Hills, CA) provides this irrigation method by delivering a flow of irrigants from the tip into the pulp chamber, while excess fluid is simultaneously remover using a second component of the system

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responsible for its evacuation. Studies indicate that the use of GentleWave achieves a success rate of 97% in endodontic interventions in vital teeth and teeth with apical periodontitis [18]. This technique minimizes instrumentation of the root canal, as the applicator is introduced into the pulp chamber without entering the canals [19]. Therefore, canal enlargement to sizes ranging from 15 to 25 ISO is sufficient. In contrast, ultrasonic activation requires canal enlargement of 30-35 for the introduction of the activator 2-3mm from the apical foramen [20]. However, there is still no consensus regarding smaller canal enlargement to prevent root fractures [21]. Multisonic activation reduces the working time in the root canal system while providing effective irrigation, but its widespread use is limited due to the high cost of the system [22].

– Continuous irrigation during instrumentation. The most well-known instrument for this type of irrigation is the Self-Adjusting File (SAF, ReDent Nova, Ra'anana, Israel), which is a hollow tube-like file with a thin nickel-titanium mesh wall with a rough surface. This ensures minimal dentin removal when applying vibration-like scraping movements, maintaining minimal invasiveness during the procedure. The irrigation solution is delivered through the file system throughout the entire process of cleaning and shaping the root canal. This is achieved by using two different systems: the VATEA Irrigation Pump and the All-in-one Endostation Machine [23]. SAF does not allow for controlling apical enlargement, thus limiting the ability to achieve effective and predictable disinfection by irrigants.

– Activation using rotary instruments. For this method, Max Wire alloy files (FKG Dentaire, La Chaux de Fonds, Switzerland) are used, with XP-Endo Finisher being a representative example. It is made of highly flexible Max Wire and can act in two phases: austenitic and martensitic. It has zero taper with a tip size of 25 ISO. It has a high capability for spatial expansion, which can reach up to 6 mm in diameter. Additionally, it reaches untreated portions inside the root canal without the need for additional dentin preparation or changing the obtained shape of the root canal. Recent research indicates that XP-Endo Finisher, when used

with a standard irrigation protocol, fails to make the apical portion debris-free [24]. However, an analysis of studies suggests that there are no advantages to using XP-Endo Finisher in terms of its impact on the bacterial composition of the root canal [25].

Conclusions. Based on the results of a series of studies, the activation of irrigants provides a prolonged antimicrobial effect by enhancing the diffusion of intra-canal antiseptics, their hydrolytic and antibacterial efficacy, thereby promoting predictability in endodontic treatment. When comparing the effectiveness of different methods of irrigant activation, clinical evidence highlights the effectiveness of multisonic activation, which challenges the traditional concept of endodontic treatment by significantly reducing the necessary root canal enlargement for adequate irrigation. However, the high cost of the system limits its widespread use. According to the results of several studies, none of the individual techniques of irrigant activation allows achieving ideal cleanliness in the root canal. This, in turn, indicates the absence of a unified protocol that would provide consistent irrigation effectiveness and prolonged results in endodontic treatment of teeth.

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