Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

IRRIGATION METHODS AND PROTOCOLS IN ENDODONTICS

Madrid, academic year 2024/2025

Identification number: 97

RESUMEN

Introducción : Muchos factores pueden influir en el resultado del tratamiento del conducto radicular. Entre ellos se encuentran los irrigantes y los métodos de irrigación utilizados, que son fundamentales en endodoncia. La irrigación ayuda a limpiar, desinfectar y lubricar el sistema de conductos radiculares. Existen diferentes irrigantes como el hipoclorito sódico, el ácido etilendiaminotetraacético y la clorhexidina. Los métodos de irrigación son la irrigación manual y manual con aguja dinámica, la irrigación ultrasónica, la irrigación con presión negativa, la irrigación activada por láser, la irrigación EDDY y el XP endo finisher. **Objetivos :** Nuestro objetivo es evaluar los mejores métodos de protocolos de irrigación para controlar la infección en el tratamiento de conductos radiculares. **Metodología :** Esta revisión se realizó mediante la base de datos completa Medline junto con términos MeSH y la pregunta PICO. **Resultados :** La investigación presentó un total de 363 artículos. Tras eliminar los artículos duplicados y aplicar nuestros criterios de inclusión y exclusión, se incluyeron un total de 17 estudios. **Conclusiones :** Los mejores métodos de protocolos de irrigación para controlar la infección en el tratamiento del conducto radicular es utilizar 25 mL de hipoclorito sódico como irrigante principal del 5,25 %, dejándolo en el conducto durante 5 minutos mediante el empleo de irrigación activada por láser. Aunque el hipoclorito sódico sigue siendo el estándar de oro, se aplica ácido etilendiaminotetraacético para el enjuague final del tratamiento del conducto radicular durante al menos 1 minuto y después hipoclorito sódico para eliminar la capa de barrillo dentinario.

PALABRAS CLAVE

Odontología, endodoncia, irrigación, métodos y protocolos, tratamiento de conductos.

ABSTRACT

Introduction : Many factors can influence the outcome of the root canal treatment. Among them are the irrigants and irrigation methods used which are fundamental in Endodontics. Irrigation helps clean, disinfect as well as lubricate the root canal system. There are different irrigants such as sodium hypochlorite, ethylenediaminetetraacetic acid and chlorhexidine. The irrigation methods are manual and manual dynamic needle irrigation, ultrasonic irrigation, negative pressure irrigation, laser-activated irrigation, EDDY irrigation and XP endo finisher. **Objectives :** Our objective is to evaluate the best irrigation protocols methods in order to control infection in root canal treatment. **Materials and Methods :** We conducted this review by means of the Medline complete database together with MeSH terms and the PICO question. **Results :** The research presented a total of 363 articles. After removing duplicate articles and applying our inclusion and exclusion criteria, a total of 17 studies were included. **Conclusions :** The best irrigation protocols methods in order to control infection in root canal treatment is using 25 mL of sodium hypochlorite as the main irrigant of 5,25 %, leaving it in the canal for 5 minutes by employing laser-activated irrigation. Even though sodium hypochlorite remains the golden standard, ethylenediaminetetraacetic acid is applied for the final rinse of the root canal treatment for at least 1 minute and then sodium hypochlorite to eliminate the smear layer.

KEYWORDS

Dentistry, endodontics, irrigation, methods and protocols, root canal treatment.

INDEX

1. INTRODUCTION

1.1 Endodontics

Since the dawn of time, dentistry evolved so much that we can now treat and diagnose pulp and periapical pathologies with advanced technologies and precision. This segment of dentistry is called endodontics. The main treatment in endodontics is the root canal treatment. It consists of removing the pulp through the use of instrumentation by using manual files with standardized sizes and/or rotatory files and irrigation. It often gives the tooth another chance before being extracted (1). These infections are generally caused by caries that are not treated and that develop till reaching the pulp or caries that develop under a restoration which can make it to the pulp and cause infections. Therefore, we need to ensure the killing of many bacteria that persist in the root canal (2). Moreover, there are other pulp treatments such as direct pulp capping (placement of a material on dentin where there is exposed pulp), indirect pulp capping (placement of a material on dentin near the pulp) or pulpotomy (deletion of the coronal portion of the pulp leaving the radicular pulp vital) (3).

1.2 Factors that influence the success of an endodontic treatment

Numerous factors can influence the outcome of a root canal treatment. The factors that can affect it are tooth anatomy and location, pulp vitality, periapical tissue pathologies, instrumentation, obturation, isolation and issues encountered during the root canal treatment (perforations, broken file in a root canal, not finding all the root canals). Finally, irrigation is one of the main pillars for the success of endodontic treatment (4,5).

1.2.1 Tooth anatomy and location

Tooth anatomy and location are factors that can influence the success of a root canal treatment. Each tooth has its anatomy and can vary immensely from having one or multiple roots, absence or presence of curvature in the roots, absence or presence of calcification in the roots. Single-rooted teeth are more prone to success in a root canal treatment compared to multi-rooted teeth because multi-rooted teeth have a more complex anatomy and their posterior location in the mouth generates a reduced field of vision along with a complexity of manipulation of instruments and materials due to less space. Moreover, the presence of curvatures and the degree of curvatures decrease the success of the root canal treatment because of the intricacy of preparing the root canal. Despite the fact that the dentist has the possibility to have pre-curved instrumentation files according to the curvature, there is an increased risk of broken files or incapacity of obtaining an optimal cleaning of the root canal. Finally, the presence of root calcifications creates obstructions and can impede the path for preparing the root canal. These anatomical characteristics make the root canal therapy a laborious task (6).

1.2.2 Pulp vitality

The diagnosis of the pulp is essential in order to conduct a treatment plan. There are different pulp pathologies including reversible pulpitis, symptomatic or asymptomatic irreversible pulpitis, necrosis and endodontically treated tooth (7). Depending on the pulp pathology, the prognosis of the tooth and accordingly the success of the root canal therapy will be altered. The more vital the pulp is the greater the success of a root canal therapy and inversely. For an endodontically treated tooth, the chances of success of retreatment depend greatly on the quality of the previous root canal therapy and the presence of an intra-radicular post or not thus the chances of success are even lower than a tooth with a vital pulp (5).

1.2.3 Periapical tissues pathologies

The periapical tissues consist of the cementum, periodontal ligament and the surrounding bone of the tooth. To diagnose it, the dentist conducts a palpation and percussion test along with a radiographic image which can help us identify a radiolucent or radiopaque image surrounding the apex of the tooth. There are different diagnoses possible for the periapical tissues which are : healthy periapical tissues, symptomatic or asymptomatic apical periodontitis, acute or chronic apical abscess and condensing osteitis (7). The presence of apical periodontitis leads to a decrease in the success of root canal therapy compared to healthy periapical tissues. Additionally, teeth accompanied by a small lesion (less than 5 mm) have more success in root canal therapy than teeth with a bigger lesion. It can be explained by the fact that bigger lesions would suggest a longer duration presence which implies further proliferation of bacteria and increased resistance to treatment (4).

1.2.4 Instrumentation

Instrumentation is an essential foundation in order to complete a root canal therapy. The conventional technique is the manual technique using files made from stainless steel usually with different types such as the K files. Then, in 1991 the NiTi rotary files were introduced in the market, marking a pivotal point in the endodontic treatment. They are made from nickel and titanium and present various system : WaveOne, ProTaper, Mtwo… They have numerous advantages compared to manual stainless steel files : faster to use, more reliable and more flexible. We have the choice between manual and rotary for a root canal therapy however to increase our chances of success in a root canal therapy, rotary instruments would be used. Finally, between the different rotary systems we can find ones that provide us with a greater chance of success in treatment (8).

1.2.5 Irrigation

The type of irrigant, the concentration, the time of exposure, the volume of irrigant and the temperature affect the chances of success of root canal therapy. Each irrigant is different and has its advantages and disadvantages. Sodium hypochlorite (from 0,5 to 8,25 %), ethylenediaminetetraacetic acid (15 to 17 %), chlorhexidine (2 %) and saline solution (0,9 %) are irrigants that can be utilized in endodontics. For the time of exposure, sodium hypochlorite and ethylenediaminetetraacetic acid are more powerful when applied longer in the root canal system. Conventionally, at least 1 minute of irrigation is preferred. The volume of irrigants introduced in the root canal is around 5 to 15 milliliters. Another method of activation of an irrigant is temperature as it increases the reaction rate and enhances the antimicrobial property. The irrigant can be heated preheated or heated inside the root canal (9). Sodium hypochlorite is more powerful when heated from 20 to 60 degrees Celsius depending on the concentration (10).

1.2.6 Obturation

Remnant bacteria in the root canal system is one of the main causes of failure of a root canal therapy, for that reason, obtaining an adequate obturation is essential. It is the process of filling the root canal homogenously with a material to seal it and prevent further infections. Gutta-percha is commonly used as a sealant. There are different techniques to obturate the root canal : lateral condensation technique which is highly common and used technique, warm vertical compaction, warm lateral compaction, continuous wave compaction technique, thermoplasticized injection technique, carrier-based gutta-percha, thermomechanical compaction and chemically plasticized gutta percha technique. The choice of the material and technique of obturation of the root canal system depends on the shape of the root canal, the presence of curvatures and the knowledge and experience of the dentist (11). Furthermore, to obtain a hermetic seal the gutta percha needs cement (12). This viscous paste also serves as a lubricant and fills lateral canals as well as space left empty. The overextension of the filling material can happen and decrease the chances of success of a root canal therapy (4). Therefore, the obturation procedure influences the success of a root canal therapy depending on the quality and the choice of material along with the obturation technique. Modern obturation techniques are more effective than traditional techniques because of their enhanced filling quality, reduced leaking incidence and superior homogenous fillings (11).

1.2.7 Isolation

Isolation of a tooth is the process of setting apart the tooth from the mouth. The goal is to reduce microorganisms being transferred between the oral cavity and the tooth, to reduce the risk of an instrument or a material being swallowed, the patient feels more protected and it provides moisture control. There are two types of isolation in dentistry : relative isolation and total isolation. Relative isolation is achieved by using cotton rolls positioned in vestibular if the tooth is on the upper arch and vestibular and lingual if the tooth is on the lower arch. They will help mainly by absorbing the saliva and protecting the surrounding tissues. Total isolation requires the application of a latex rubber dam where the tooth will protrude through a perforation, a clamp positioned on the tooth along with a frame to stretch the rubber dam. This provides safety for the patient, protection for the surrounding tissues and the oral cavity and prevents the spreading of oral pathogens. The contraindications for a total isolation would be a latex allergy and asthma. The use of total isolation will improve the success of a root canal therapy compared to a relative isolation and even less chances of success if the dentist did not use any isolation method (13).

1.2.8 Issues encountered during the root canal treatment

Despite the new technologies and advancements made in endodontics, issues during the root canal therapy can occur : not finding all the root canals of the tooth, perforations and broken files in the root canal. There is a possibility to miss a root canal and it decreases the chances of success of a root canal therapy because the cleaning of the infection is not completed. The breakage of an instrument like a file can happen if the bending of the file is amplified for example, which can lead to a decrease of the chances of success of a root canal because it will impede the instrumentation, obturation and irrigation process to be completed. Moreover, the stage of the treatment when this issue occurs affects more or less the success of the root canal therapy (14). Finally, perforations of the pulp chamber or the root canal occur during the stage of instrumentation which gives access to infection and microorganisms to the root canal system. In many cases of perforations, the tooth is going to be extracted as the chances of success of the root canal therapy are low. The incidence of this problem can be avoided depending on the experience of the dentist (15).

1.3 Types of irrigation

As the anatomy of the root canal system is complex, instrumentation is insufficient to clean and eliminate organic and inorganic products. Consequently, irrigation braces the work of the instrumentation by chemically removing pulpal, bacterial and dentinal debris in the root canal system. However, there is no ideal irrigant that accomplishes all the requirements that we demand, that is why dentists have the ability to utilize a single or multiple irrigants on the tooth. There are different types of irrigants that we can use during a root canal treatment namely sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA), chlorhexidine and saline solution (16).

1.3.1 Sodium hypochlorite

Sodium hypochlorite is one of the most used and common irrigants in endodontic treatments. Its chemical formula is NaOCl and it is considered the irrigant of choice. The main action is to dissolve organic components, disinfect and serve as a lubricant but does not have the ability to eliminate hard tissue debris from the instrumentation (inorganic component). It is used during the instrumentation of the root canal and as a final irrigation. Free chlorine is the most important element to achieve when using this irrigant because it is the one that dissolves the pulp and organic debris. Consequently, It will dictate the reactivity of sodium hypochlorite. The effectiveness of this irrigant depends greatly on the concentration and volume flowing in the root canal. The pH can range between 11 to 13 and the concentration can go from 0,5 to 8,25 %. The dakin solution is at 0,5%, the diluted version is at 2,5% but these are not often used in endodontics and finally, the pure solution is at 5,25% which is generally used in endodontics (16). Ultimately, the 8,25 % solution of sodium hypochlorite was proposed as a result of the conception of the single-instrument system which needed a faster and more powerful irrigant (17). Moreover, sodium hypochlorite is not considered toxic if it is enclosed in the root canal, except when the periapical tissues are exposed to it. The release of sodium hypochlorite surpassing the apical foramen leads to inflammation, necrosis and ulceration of tissues. This NaOCl accident can be caused by the dentist's wrong management of the irrigation (18).

1.3.2 Ethylenediaminetetraacetic acid

Ethylenediaminetetraacetic acid (EDTA) is an irrigant utilized as an adjunct to sodium hypochlorite in root canal therapy because ethylenediaminetetraacetic acid removes inorganic components (the smear layer) through the medium of calcium chelation : it replaces the calcium ions that are united to the dentin. It is a chelator involved generally in the final irrigation protocol. The percentage of ethylenediaminetetraacetic acid is from 15 to 17 % and presents a pH of 7 to 8 (16).

1.3.3 Chlorhexidine

Chlorhexidine is a cationic bisbiguanide irrigant. Its main function is antiseptic and has the capacity to bind to dentin and achieve a sustained antimicrobial activity : this is called subtantivity. However, chlorhexidine does not have the power to remove organic components. In endodontics, it can also be employed as an intracanal medication. The percentage of chlorhexidine is 2% and it is presented in the form of liquid or gel. The pH ranges between 5,5 to 7 (16). Finally, chlorhexidine can an alternative to sodium hypochlorite due to its antimicrobial properties and no toxicity (17).

1.3.4 Saline solution

Saline solution is an irrigant often used in the final irrigation process along with sodium hypochlorite due to the fact that these two irrigants mixed together do not produce precipitation. The disadvantages of saline solution are inefficient antimicrobial effect and incapacity of removal of the organic components (19). The percentage of saline solution is 0,9 % of sodium chloride (20).

1.4 Irrigation methods

The dentist has multiple options for choosing the type of irrigant but he also has the choice of selecting the method of conveying this irrigant in the root canal. The irrigation method will determine the effectiveness of the irrigant. There are different techniques to deliver the irrigant in the root canal system : manual needle irrigation, manual dynamic needle irrigation, ultrasonic irrigation, negative pressure irrigation, laser-activated irrigation and Eddy irrigation. The form of activation of the conventional irrigation techniques is the positive pressure, however newer techniques have other forms of activation which can be the negative pressure, the ultrasonic, the sonic and the laser activation (19).

1.4.1 Manual needle irrigation and manual dynamic needle irrigation

The traditional way to irrigate the root canal system is with the manual irrigation system which is done with the syringe and a needle with lateral exit (positive pressure). It is done by inserting the syringe filled with the irrigant linked to the needle into the root canal at 2 to 3 millimeters less than the working length, injecting the irrigant by performing up and down movement of the syringe. This technique is easy to use and inexpensive but it has some disadvantages like the difficulty of penetration in a tooth with a challenging morphology and a vaporlock (it is the air bubbles formation) would create in the apical third of the tooth. Then there is manual dynamic needle irrigation which is identical to manual needle irrigation but adds just one step for the irrigation. When performing the irrigation with a needle, the dentist inserts a gutta percha or a file in the root canal and executes an upward and downward movement. This will generate displacement of the irrigant and it will help reduce the vaporlock effect and improve the cleaning (20).

1.4.2 Ultrasonic irrigation

The ultrasonic irrigation method helps to agitate the irrigant in the canal with the ultrasonic file that oscillates at 25 to 30 kHz. It is inserted at approximately 2 millimeters less than the working length. This would facilitate the distribution of the irrigant in difficult and deeper spaces of the root canal (21,22). There are two types of ultrasonic irrigation method : active and passive (19).

1.4.3 Negative pressure irrigation

Negative pressure irrigation is a method to deliver the irrigant without the vaporlock effect by a flow of the irrigant and suction effect with the use of the syringe. Its main advantage is to reduce the risk of extrusion of the irrigant from the apical foramen which reduces the probability of occurrence of sodium hypochlorite accident (21,22). Endovac system is an example of a negative pressure irrigation. It uses a master delivery tip and a microcannula or a macrocannula. Therefore, the master delivery tip supplies the irrigant and eliminates the excess of irrigant to avert overflow. Then, the cannula produces negative pressure by pulling away the irrigant (19).

1.4.4 Laser activated irrigation

Laser activated irrigation method is a device with an optical fiber tip inserted in the root canal with the irrigant, it heats it past boiling point which creates bubbles that explode after a certain volume and create a cavitation effect. Therefore, this will generate a photoacoustic agitation of the irrigant so it flows everywhere in the root canal system. Erbium Yag (Er-Yag) is an example of a laser irrigation method that sends wavelength at 2940 nm (23).

1.4.5 Eddy irrigation

The eddy irrigation method is a sonic irrigation system that uses a flexible single-use polyamide tip. It functions in the range of frequency of 5000 to 6000 Hz (24). It works by generating a three-dimensional action that produces cavitation and acoustic streaming which allow it to clean efficiently the root canal system (25).

1.4.6 XP endo finisher

The XP endo finisher is a method of irrigation utilizing a rapid liquid movement that cleans and removes debris by friction. It comprises a non-tapered, non-cutting tip made out of nickel and titanium which gives it shape memory. The size of the instrument is ISO size 25 hence, the XP endo finisher has the easiness to irrigate curved canals. During insertion of the XP endo finisher in the root canal, the body temperature produces the expansion of the instrument and when activated, it achieves a hemi circular movement. This irrigation method is generally employed in the final irrigation steps (19).

Justification : One of the main pillars of endodontics is irrigation. It plays a crucial role in cleaning, disinfecting and lubricating the root canal. Nowadays, sodium hypochlorite is still the golden standard however the method of usage, the volume, the concentration and the energy sources are the factors that can enhance the chances of eliminating microorganisms. Accordingly, selecting the right factors is fundamental to increase the chances of success of a root canal therapy.

2. OBJECTIVE

Our objective in this review is to evaluate the best irrigation protocols methods in order to control infection in root canal treatment.

3. MATERIAL AND METHODS

Research question :

In order to conduct this research, we utilized the PICO (Patient, Intervention, Comparation, Outcome) structure and established this research question : In endodontic treatment, is there a difference between the types of irrigants and methods of irrigation in terms of the success of the treatment ?

Table 1. PICO system.

Patient	Root canal treatments
Intervention	Types of irrigants
Comparison	Methods of irrigants
Outcome	Success of the treatment

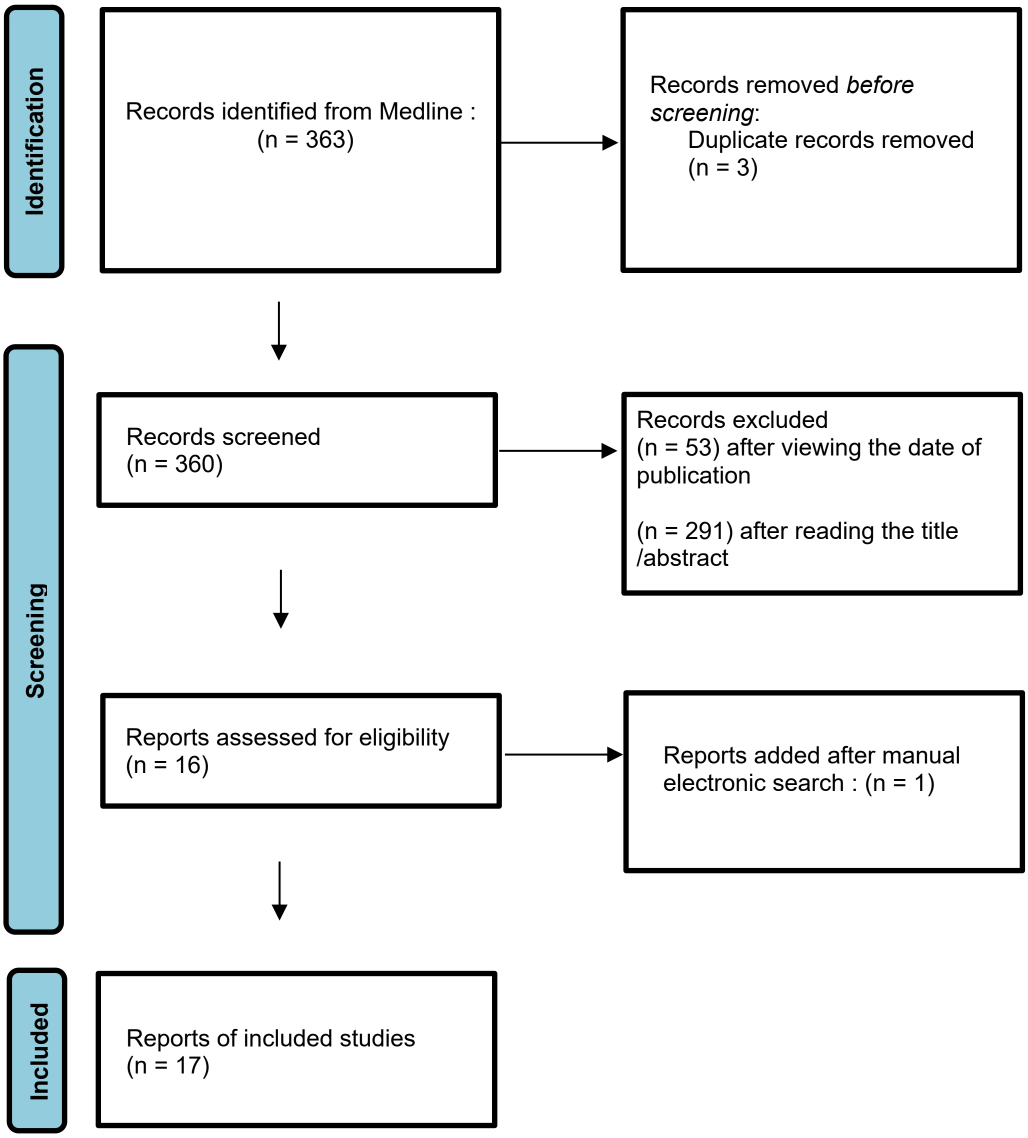
We chose articles based on criterias that make them eligible for the usage of this review. An initial selection of articles was included based on their title. Articles that are less than 10 years old are included. Articles about the types of irrigants and methods of irrigation are included. Articles about the type of irrigation and method of irrigation that did not fit in the eligibility criterias were excluded. Articles about the properties of the irrigants and the type of irrigation were included. Duplicates of articles are excluded.

The database of Medline complete helped us perform the bibliographic research. MeSH (Medical Subject Headings) terms were used along with free terms, in single or multiple combinations with the use of Boolean operators (and, or, not). Then, the duplicate articles were eliminated by working with the program called Rayyan.

The search equation employed in the database of Medline complete in the language English is :

((Irrigants [MeSH term]) OR best irrigants) AND/OR (Irrigation methods [MeSH term] OR irrigation protocols)).

Table 2. PRISMA flow chart (26).



The first search conducted of our review on the database Medline complete gave us a total of 363 articles. Then, thanks to the program Rayyan the duplicate articles were eliminated before the screening. Afterward, at the beginning of the screening we excluded 291 articles after reading the title and the abstract and 53 articles after viewing the date of publication (we excluded articles published more than 10 years ago). Hence, after applying our inclusion criteria, 16 articles were selected. Additionally, a manual electronic was realized which added 1 article. Finally, after completing screening a total of 17 studies were included in this review.

4. RESULTS

Table 3. Review articles evaluating the type of irrigant.

Author / Year	Time of study	Study design	Evaluation	Intervention	Comparison
Chen Cai, Xuan Chen, Yang li and Qianzhou Jiang (2023) (27)	In vitro	In vitro	Type of irrigant	Sodium hypochlorite	None
Kapil Naladkar, Manoj Chandak, Swayangprabha Sarangi, Paridhi Agrawal, Namrata Jidewar, Tejas Suryawanshi, Palak Hirani (2024) (21)	None	Review	Type of irrigant	Sodium hypochlorite	Chlorhexidine and EDTA
Mirza, Mubashir Baig, Sharma, Kirti, Shetty, Chitharanjan, Gupta, Jayantika, Padariya, Kinjal, Chohan, Hitesh, Pius, Alen (2024) (28)	Not know	In vitro	Type of irrigant	Sodium hypochlorite	Chlorhexidine and EDTA

Akua B. Konadul, Patrick C. Ampofo, Moses L. Akyeh, Sandra A. Hewlett, Kofi Osei-Tutu, Ebenezer A. Nyako (2024) (29)	10 months	Prospective cohort sudy	Type of irrigant	Sodium hypochlorite	None
Esin Özlek, Eda Acikgoz, Nesibe Zeyneb Gökkaya, Ahmet Taşan, Fikret Altındağ (2023) (30)	Not known	In vitro	Type of irrigant	Sodium hypochlorite	EDTA

The table 3 summarizes the information gathered from articles concerning the type of irrigant. This table is composed of 6 categories corresponding to the authors, the year of publication which ranges from 2023 to 2024, the time of study, the study design, the evaluation describing the property, the intervention which is sodium hypochlorite and comparison which are ethylenediaminetetraacetic acid and chlorhexidine.

Table 4. Review articles evaluating concentration of the irrigant.

Author / Year	Time of study	Study design	Evaluation	Intervention	Comparison
Chen Cai, Xuan Chen, Yang Li, Qianzhou Jiang (2023) (27)	Not known	In vitro	Concentration	1 % sodium hypochlorite	2,5 % sodium hypochlorite and 5,25 % sodium hypochlorite
Mohammad Forough Reyhani, Yousef Rezagholizadeh,	Not known	In vitro	Concentration	1 % sodium hypochlorite	2,5 % sodium hypochlorite and

Mohammad Reza Narimani, Lotfollah Rezagholizadeh, Mohammad Mazani, Mohammad Hossein Soroush Barhaghi, Yavar Mahmoodzadeh (2017) (31)					5,25 % sodium hypochlorite
Akua B. Konadul, Patrick C. Ampofo, Moses L. Akyeh, Sandra A. Hewlett, Kofi Osei-Tutu, Ebenezer A. Nyako (2024) (29)	10 months	Prospective cohort study	Concentration	0,5 % sodium hypochlorite	1 % sodium hypochlorite, 2,5 % sodium hypochlorite and 5,25 % sodium hypochlorite
Esin Özlek, Eda Acikgoz, Nesibe Zeyneb Gökkaya, Ahmet Taşan, Fikret Altındağ (2023) (30)	Not known	In vitro	Concentration	2,5 % sodium hypochlorite	5,25 % sodium hypochlorite
S. S. Virdee, D. J. J. Farnell, M. A. Silva, J. Camilleri, P. R. Cooper, P. L. Tomson (2020) (32)	Not known	In vitro	Concentration	2 % sodium hypochlorite	5,25 % sodium hypochlorite

The table 4 summarizes the information gathered from articles concerning the concentration of the irrigant. This table is composed of 6 categories corresponding to the authors, the year of publication which ranges from 2017 to 2024, the time of study, the study design, the evaluation describing the property assessed, the intervention which is sodium hypochlorite (from 0,5 % to 2,5 %) and comparison which is sodium hypochlorite (from 1 % to 5,25 %).

Table 5. Review articles evaluating the exposure time of the irrigant.

Author / Year	Time of study	Design study	Evaluation	Intervention	Comparison
Chen Cai, Xuan Chen, Yang Li, Qianzhou Jiang (2023) (27)	Not known	In vitro	Exposure time	1 minute	3 minutes, 5 minutes, 7,5 minutes and 15 minutes
Kapil Naladkar, Manoj Chandak, Swayangprabha Sarangi, Paridhi Agrawal, Namrata Jidewar, Tejas Suryawanshi, Palak Hirani (2024) (21)	None	Review	Exposure time	At least 1 minute	None
X. Petridis, F. H. Busanello, M. V. R. So, R. J. B. Dijkstra, P. K. Sharma, L. W. M. van der Sluis (2019) (34)	Not known	In vitro	Exposure time	1 minute	3 minutes, and 5 minutes

The table 5 summarizes the information gathered from articles concerning the exposure time of the irrigant. This table is composed of 6 categories corresponding to the authors, the year of publication which ranges from 2019 to 2024, the time of study, the study design, the evaluation describing the property assessed, the intervention which is 1 minute of exposure time and comparison which is 3 to 15 minutes of exposure time.

Table 6. Review articles evaluating temperature.

Author / Year	Time of study	Study design	Evaluation	Intervention	Comparison
Kamran Gulsahi, R. Ebru Tirali, S. Burcak Cehreli, Zeynep Ceren Karahan, Emel Uzunoglu, Bizden Sabuncuoglu (2014) (33)	3 weeks	In vitro	Temperature	25 degrees Celsius	37 degrees Celsius
Aldo del Carpio-Perochena, Clovis Monteiro Bramante, Marco Hungaro Duarte, Flaviana Bombarda de Andrade, Marcia Zardin Graeff, Marina Marciano da Silva, Bruno Cavalini Cavenago, Samuel Lucas Fernandes (2015) (34)	Not known	In vitro	Temperature	22 degrees Celsius	37 degrees Celsius

The table 6 summarizes the information gathered from articles concerning the temperature of the irrigant. This table is composed of 6 categories corresponding to the authors, the year of publication which ranges from 2014 to 2015, the time of study, the study design, the evaluation describing the property assessed, the intervention which is 22 to 25 degrees Celsius and comparison which is 37 degrees Celsius.

Table 7. Review articles evaluating volume of the irrigant.

Author / Year	Time of study	Study design	Evaluation	Intervention	Comparison
Kapil Naladkar, Manoj Chandak, Swayangprabha Sarangi, Paridhi Agrawal, Namrata Jidewar, Tejas Suryawanshi, Palak Hirani (2024) (21)	None	Review	Volume	Significant volume	None
X. Petridis, F. H. Busanello, M. V. R. So, R. J. B. Dijkstra, P. K. Sharma, L. W. M. van der Sluis (2019) (35)	Not known	In vitro	Volume	20 uL	40 uL
Buvaneshwari Arul, Nandini Suresh, Ranjithkumar Sivarajan, Velmurugan Natanasabapathy (2021) (36)	Not known	Randomized clinical trials	Volume	6 mL, 12 mL and 18 mL	25 mL

The table 7 summarizes the information gathered from articles concerning the volume of the irrigant. This table is composed of 6 categories corresponding to the authors, the year of publication which ranges from 2019 to 2024, the time of study, the study design, the evaluation describing the property assessed, the intervention which is 20 uL to 18 mL and comparison which is 40 uL to 25 mL.

Table 8. Review articles evaluating the mode used with irrigation.

Author / Year	Time of study	Study design	Evaluation	Intervention	Comparison
Mohan D Pujari, Maneesha Das,	1 year	In vitro	Mode	Conventional needle	EndoVac system and

Asutosh Das, Dinesh G Kamath, Junu Henry, Arun Shyam, Doaa M Alhaleis (2024) (37)					Passive ultrasonic irrigation
David Donnermeyer, PD Dr.med.dent., Patricia Claire Dust, Cand.med.dent., Edgar Schafer, Prof.Dr.med.dent., Sebastian Burklein, Prof.Dr.med.dent. (2024) (38)	Not known	In vitro	Mode	Conventional needle	Manual irrigation, EndoVac system, Ultrasonically activated irrigation And Laser-activated irrigation
Siavash Jafari Semnani a, Kiumars Nazari Moghadam a, Zahra Jafari a, Nasim Chiniforush (2024) (39)	Not known	In vitro	Mode	Conventional needle	Ultrasonic activation and Laser-activated irrigation
Keerthika Rajamanickam, Sandhya Raghu, J Vijayashree Priyadharsini, Delphine Priscilla Antony, Nivedhitha Malli Sureshbabu (2023) (40)	Not known	Randomized clinical trials	Mode	Conventional needle	Laser-activated irrigation
Warley Oliveira Silva, Pablo Amoroso-Silva, Patrícia Olivares, Murilo Priori Alcalde, Flávio Rodrigues Ferreira	Not known	In vitro	Mode	XP-endo finisher	Passive ultrasonic irrigation

Alves, Marília Fagury Marceliano-Alves (2023) (41)					
Hair Salas, Andrés Castrejon, Dante Fuentes, Alexandra Luque, Edson Luque (2020) (25)	Not known	In vitro	Mode	Conventional needle	Passive ultrasonic irrigation and Eddy irrigation system

The table 8 summarizes the information gathered from articles concerning the mode used with the irrigant. This table is composed of 6 categories corresponding to the authors, the year of publication which ranges from 2020 to 2024, the time of study, the study design, the evaluation describing the property assessed, the intervention which is the conventional needle and XP-endo finisher and comparison which is the EndoVac system, ultrasonic irrigation system, Eddy irrigation system and Laser-activated irrigation.

There are 17 articles selected for this review.

5. DISCUSSION

To be able to achieve a root canal treatment, irrigation is needed. The choice is limited to a few such as sodium hypochlorite, ethylenediaminetetraacetic acid and chlorhexidine. Our first objective is to compare the irrigants to have great success in the treatment. Sodium hypochlorite remains the gold standard for irrigation in Endodontics as it dissolves the organic tissue and is antimicrobial which are the properties needed for an irrigant (21,27,28,30). Nonetheless, sodium hypochlorite is not flawless as it does not dissolve inorganic tissue in particular the smear layer which the irrigation process must clear out of the root canal system. As a consequence, in the final rinse of the irrigation process, ethylenediaminetetraacetic acid is utilized to eliminate the smear layer to smooth out the root canal and facilitate the obturation later on (21,30). Additionally, chlorhexidine can be used as an irrigant as it is antimicrobial as well as lesser cytotoxicity compared to sodium hypochlorite and ethylenediaminetetraacetic acid. However, it is rarely used as main irrigant in a root canal treatment due to a moderate organic tissue dissolution, a strong odor and taste along with the inability to mix it with sodium hypochlorite as it creates a detrimental effect (28). Thus, the irrigant of choice is sodium hypochlorite with a final rinse of ethylenediaminetetraacetic acid preceded and followed by a rinse of sodium hypochlorite in an effort to prevent dentin erosion (21,27–30). As sodium hypochlorite is the irrigant of choice, knowing the concentration of this irrigant is crucial. It exists in varying concentrations from 0,5 % to 5,25 %. The concentrations of 0,5 % and 1 % of sodium hypochlorite are not effective enough in terms of killing the bacteria independently of the mode of irrigation. Then, the concentrations of 2,5 % and 5,25 % are effective regarding its antimicrobial properties. Overall, the higher the concentration of sodium hypochlorite the better and the greater the success of the root canal therapy (27,29–32). Moreover, the time we leave the irrigant in the root canal has an impact on the outcome. According to Cai C et al. (27), 1 minute of exposure is not enough to kill bacteria but 3 minutes as well as 5 minutes are enough but they found a saturation level after 5 minutes. Then for this article Naladkar et al. (21), it talks about the time of exposure of ethylenediaminetetraacetic acid which is at least 1 minute. In the article Petridis et al. (35), they found that there is no notable difference between 1 minute and 2 minutes of exposure of sodium hypochlorite whereas for the 5 minutes exposure they found a consequential difference in the dissolution of the biofilm. To summarize, 5 minutes of exposure of sodium hypochlorite in the root canal is the best amount of time to improve the success of the treatment. A controversial factor that can alter the outcome of the treatment is the temperature. According to articles, we can heat sodium hypochlorite to 22 - 25 degrees Celsius which can correspond to room temperature or to 37 degrees Celsius identical to the average temperature of the human body. Both studies discussing the effect of a temperature of 37 degrees Celsius, concluded that at this level of temperature the properties of the sodium hypochlorite did not improve or even was more anti-fungal than antimicrobial which is not required in a root canal therapy. However, at 22 - 25 degrees Celsius, sodium hypochlorite is effective for eliminating bacteria in the root canal. To conclude, temperature does not have a great effect on the efficacy of sodium hypochlorite (33,34). In addition to the temperature, there is also the volume of irrigant utilized. According to Naladkar et al. (21), using a significant volume of sodium hypochlorite disinfects the root canals but this study does it specify a specific amount of volume. However, it does specify a volume of 5 to 10 mL for the ethylenediaminetetraacetic acid used in the final irrigation process. For the second study, Petridis et al. (35), it proves that using 40 uL is more efficient in time to kill bacteria than 20 uL. For the third study, Arul et al. (36), they compared 6, 12, 18 and 25 ml and deducted that 12 or 18 mL is better for reducing microhardness of the dentin in the root canal than 6 mL of volume. For the volume of 25 mL, results are even superior in the matter of reduction of microhardness of the dentin compared to the 12 or 18 mL results. Hence, increasing the volume of irrigants is beneficial for cleaning and disinfecting the root canal system. We recommend a volume of 25 mL of sodium hypochlorite for the root canal therapy. The last factor is the way of delivering the irrigant. The first article found that EndoVac system is more efficient for the elimination of the smear layer than passive ultrasonic irrigation system and conventional irrigation (37). The second article found that laser-activated irrigation is better in the removal of the bacteria than conventional needle irrigation, manual irrigation, EndoActivator system, EDDY system and ultrasonic activation system (38). For the third article, they demonstrated that laser-activated irrigation can enhance the penetration depth of the irrigant which generates a better cleaning of the canal. It was compared to ultrasonic activation system and conventional irrigation (39). For the fourth article established that laser-activated irrigation is superior concerning the decline of bacteria compared to conventional neddle irrigation (40). According to Silva et al. (41), they proved that XP-endo finisher is better for cleaning the canal as it decreases the hard tissue debris relative to passive ultrasonic irrigation. In the last article, they expressed that passive ultrasonic irrigation facilitates the penetration of the irrigant in the apical third of the root canal compared to conventional needle irrigation and EDDY irrigation (25). To finalize, the mode of irrigation has an impact on the outcome of a root canal treatment and the most promising and leading technique seems to be laser-activated irrigation.

6. CONCLUSIONS

The best irrigation protocols methods in order to control infection in root canal treatment is using 25 mL of sodium hypochlorite as the main irrigant of 5,25 % regarding the concentration, leaving it in the canal for 5 minutes by employing the mode of laser-activated irrigation. Sodium hypochlorite remains the golden standard of irrigant in endodontics. Concerning temperature, heating the sodium hypochlorite did not affect the outcome of the root canal therapy hence leaving it at room temperature is recommended. For the mode, laser-activated irrigation is the most promising technique to deliver the irrigant even though all techniques displayed positive outcomes. Then, for the final rinse of the root canal treatment, irrigate the root canal of sodium hypochlorite then at least 1 minute of irrigation utilizing ethylenediaminetetraacetic acid and then sodium hypochlorite with the aim of eliminating the smear layer. Finally, additional and subsequent investigations are essential to obtain more details as well as more information about the irrigation methods and protocols in endodontics.

7. SUSTAINABILITY

In dentistry and specifically in endodontics, the topic of sustainability must be more elaborated in order to establish long-term objectives. It compasses environmental, social and economic impact. Incorporating sustainable practices in irrigation methods and protocols is vital to promote and improve the United Nations Sustainable Development Goals, in particular the sustainable development goal number 3 (good health and well-being), 9 (industry, innovation and infrastructure) and 12 (responsible consumption and production). The environmental dimension discusses the consumption of dental materials, waste management, biodegradable and non-toxic irrigants, using reusable materials and instruments, selecting a biodegradable or recyclable packaged dental materials, selecting an eco-friendly manufacturer that utilises solar panels for example and choosing an irrigant that is not chemically synthesised while remaining efficient are key factors for this aspect. Then, for the social dimension, informing patients about oral hygiene techniques and raising awareness concerning dental treatments and prevention in low socio-economic patients in order to reduce the probability of performing a root canal treatment.

8. REFERENCES

1. Levine M. Root-Canal Therapy: A Means of Treating Oral Pain and Infection. 1988;34.
2. Abbott P. Endodontics - Current and future. J Conserv Dent. 2012;15(3):202.
3. Lin LM, Rosenberg PA. Repair and regeneration in endodontics: Repair and regeneration in endodontics. Int Endod J. 2011 Oct;44(10):889–906.
4. Vieira AR, Pacheco-Yanes J, Gazzaneo ID, Neves MAS, Siqueira Jr JF, Gonçalves LS. Factors influencing the outcome of nonsurgical root canal treatment and retreatment: A retrospective study. Aust Endod J. 2024;50(2):245–59.
5. Smith CS, Setchell DJ, Harty FJ. Factors influencing the success of conventional root canal therapy—a five-year retrospective study. Int Endod J. 1993 Nov;26(6):321–33.
6. Tang L, Sun T qi, Gao X jie, Zhou X dong, Huang D ming. Tooth anatomy risk factors influencing root canal working length accessibility. Int J Oral Sci. 2011 Jul;3(3):135–40.
7. Jafarzadeh H, Abbott PV. Review of pulp sensibility tests. Part I: general information and thermal tests. Int Endod J. 2010 Sep;43(9):738–62.

8. Rajkhan W, Alasmari A, Alhadi A, Alharbi A, Khwaji N, Alannaz R, et al. Rotary endodontic files versus manual files for root canal treatment. Int J Community Med Public Health. 2021 Sep 19;8.

9. Topbaş C, Adıgüzel Ö. Endodontic Irrigation Solutions: A Review. Int Dent Res. 2017 Dec 31;7:54.

10. Sirtes G, Waltimo T, Schaetzle M, Zehnder M. The effects of temperature on sodium hypochlorite short-term stability, pulp dissolution capacity, and antimicrobial efficacy. J Endod. 2005 Sep;31(9):669–71.

11. Kapoor K. Endodontic obturation techniques: A review. Int J Health Sci. 2024 Aug 9;8(S1):1033–40.

12. Lim M, Jung C, Shin DH, Cho YB, Song M. Calcium silicate-based root canal sealers: a literature review. Restor Dent Endod. 2020 Jun 9;45(3):e35.

13. Lawson NC, Gilbert GH, Funkhouser E, Eleazer PD, Benjamin PL, Worley DC. General Dentists' Use of Isolation Techniques During Root Canal Treatment: from the National Dental Practice-Based Research Network. J Endod. 2015 Aug;41(8):1219–25.

14. Tabassum S, Khan FR. Failure of endodontic treatment: The usual suspects. Eur J Dent. 2016 Jan;10(1):144–7.

15. Vehkalahti MM, Swanljung O. Accidental perforations during root canal treatment: an 8-year nationwide perspective on healthcare malpractice claims. Clin Oral Investig. 2020 Oct;24(10):3683–90.

16. Boutsioukis C, Arias-Moliz MT. Present status and future directions – irrigants and irrigation methods. Int Endod J. 2022;55(S3):588–612.

17. Demenech LS, de Freitas JV, Tomazinho FSF, Baratto-Filho F, Gabardo MCL. Postoperative Pain after Endodontic Treatment under Irrigation with 8.25% Sodium Hypochlorite and Other Solutions: A Randomized Clinical Trial. J Endod. 2021 May;47(5):696–704.

18. Kanagasingam S, Blum IR. Sodium Hypochlorite Extrusion Accidents: Management and Medico-Legal Considerations. Prim Dent J. 2020 Dec;9(4):59–63.

19. Gomes BPFA, Aveiro E, Kishen A. Irrigants and irrigation activation systems in Endodontics. Braz Dent J. 2023 Jul;34(4):1–33.

20. Ali A, Bhosale A, Pawar S, Kakti A, Bichpuriya A, Agwan MA. Current Trends in Root Canal Irrigation. Cureus. 14(5):e24833.

21. Naladkar K, Chandak M, Sarangi S, Agrawal P, Jidewar N, Suryawanshi T, et al. Breakthrough in the Development of Endodontic Irrigants. Cureus [Internet]. 2024 Aug 16 [cited 2024 Nov 10]; Available from:

https://www.cureus.com/articles/210800-breakthrough-in-the-development-of-endodontic-irrigants

22. Cheung AWT, Lee AHC, Cheung GSP. Clinical efficacy of activated irrigation in endodontics: a focused review. Restor Dent Endod [Internet]. 2020 Dec 2 [cited 2024 Nov 7];46(1). Available from: https://doi.org/10.5395/rde.2021.46.e10

23. Huang Q, Li Z, Lyu P, Zhou X, Fan Y. Current Applications and Future Directions of Lasers in Endodontics: A Narrative Review. Bioengineering. 2023 Feb 26;10(3):296.

24. Chu X, Feng S, Zhou W, Xu S, Zeng X. Cleaning efficacy of EDDY versus ultrasonically-activated irrigation in root canals: a systematic review and meta-analysis. BMC Oral Health. 2023 Mar 17;23(1):155.

25. Salas H, Castrejon A, Fuentes D, Luque A, Luque E. Evaluation of the penetration of CHX 2% on dentinal tubules using Conventional Irrigation, Sonic Irrigation (EDDY) and Passive Ultrasonic Irrigation (PUI) techniques: An in vitro study. J Clin Exp Dent. 2021 Jan 1;13(1):e37–42.

26. PRISMA statement [Internet]. [cited 2025 Feb 11]. PRISMA 2020 flow diagram. Available from: https://www.prisma-statement.org/prisma-2020-flow-diagram

27. Cai C, Chen X, Li Y, Jiang Q. Advances in the Role of Sodium Hypochlorite Irrigant in Chemical Preparation of Root Canal Treatment. BioMed Res Int. 2023 Jan 13;2023:8858283.

28. Mirza MB, Sharma K, Shetty C, Gupta J, Padariya K, Chohan H, et al. Comparative Analysis of Various Irrigation Solutions in Root Canal Treatment. J Pharm Bioallied Sci. 2024 Jul;16(Suppl 3):S2740–2.

29. Konadu AB, Ampofo PC, Akyeh ML, Hewlett SA, Osei-Tutu K, Nyako EA. Comparative evaluation of selected concentrations of sodium hypochlorite on the outcome of endodontic therapy among Ghanaians. PloS One. 2024 Jul 8;19(7):e0306693.

30. Özlek E, Acikgoz E, Gökkaya NZ, Taşan A, Altındağ F. Histological evaluation of the debris removal efficiency of activation of sodium hypochlorite solution at different concentrations. BMC Oral Health. 2023 Jul 28;23(1):528.

31. Forough Reyhani M, Rezagholizadeh Y, Narimani MR, Rezagholizadeh L, Mazani M, Barhaghi MHS, et al. Antibacterial effect of different concentrations of sodium hypochlorite on Enterococcus faecalis biofilms in root canals. J Dent Res Dent Clin Dent Prospects. 2017;11(4):215–21.

32. Virdee SS, Farnell DJJ, Silva MA, Camilleri J, Cooper PR, Tomson PL. The influence of irrigant activation, concentration and contact time on sodium hypochlorite penetration into root dentine: an ex vivo experiment. Int Endod J. 2020 Jul;53(7):986–97.

33. Gulsahi K, Tirali RE, Cehreli SB, Karahan ZC, Uzunoglu E, Sabuncuoglu B. The effect of temperature and contact time of sodium hypochlorite on human roots infected with Enterococcus faecalis and Candida albicans. Odontology. 2014 Jan;102(1):36–41.

34. Del Carpio-Perochena A, Monteiro Bramante C, Hungaro Duarte M, Bombarda de Andrade F, Zardin Graeff M, Marciano da Silva M, et al. Effect of Temperature, Concentration and Contact Time of Sodium Hypochlorite on the Treatment and Revitalization of Oral Biofilms. J Dent Res Dent Clin Dent Prospects. 2015;9(4):209–15.

35. Petridis X, Busanello FH, So MVR, Dijkstra RJB, Sharma PK, van der Sluis LWM. Factors affecting the chemical efficacy of 2% sodium hypochlorite against oral steady-state dual-species biofilms: Exposure time and volume application. Int Endod J. 2019 Aug;52(8):1182–95.

36. Arul B, Suresh N, Sivarajan R, Natanasabapathy V. Influence of volume of endodontic irrigants used in different irrigation techniques on root canal dentin microhardness. Indian J Dent Res Off Publ Indian Soc Dent Res. 2021 Apr;32(2):230–5.

37. Pujari MD, Das M, Das A, Kamath DG, Henry J, Shyam A, et al. Assessment of Smear Layer Removal and Penetration Depth of Root Canal Irrigant Using Different Irrigation Activation Systems: A Comparative Study. J Contemp Dent Pract. 2024 Apr 1;25(4):331–4.

38. Donnermeyer D, Dust PC, Schäfer E, Bürklein S. Comparative Analysis of Irrigation Techniques for Cleaning Efficiency in Isthmus Structures. J Endod. 2024 May;50(5):644.

39. Jafari Semnani S, Moghadam KN, Jafari Z, Chiniforush N. Comparative effects of the conventional, ultrasonic, and laser-activated irrigation on penetration depth of three photosensitizers in the root canal system. Photodiagnosis Photodyn Ther. 2024 Oct;49:104286.

40. Rajamanickam K, Raghu S, Priyadharsini JV, Priscilla Antony D, Malli Sureshbabu N. Comparative Evaluation of Bacterial Reduction by Laser-Activated Irrigation Technique (LAI) With Conventional Needle Irrigation (CNI) in Single-Rooted Teeth With Pulpal Necrosis: A Single-Blinded Randomized Controlled Trial. Cureus. 2023 Dec 17;15(12):e50666.

41. Silva WO, Amoroso-Silva P, Olivares P, Alcalde MP, Alves FRF, Marceliano-Alves MF. Enhancing debris removal in curved canals: a comparative evaluation of XP-endo Finisher and Passive Ultrasonic Irrigation. Clin Oral Investig. 2023 Dec;27(12):7523–9.