UNIVERSIDADE FERNANDO PESSOA

Role of ultrasound in the endodontic retreatment: “Systematic Review”

[Papel dos ultrassons no retratamento endodôntico: “Revisão Sistemática”]

Dissertação de Mestrado

Mestrado Integrado em Medicina Dentária

Giuseppe Lombardi

Orientador:

Prof. Dr. Duarte Nuno Antunes Guimarães

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REGARDS

Dedico este espaço as pessoas que, com o seu apoio, me ajudaram nesta maravilhosa jornada de aprofundamento dos conhecimentos adquiridos ao longo destes anos

Ao meu orientador, Professor Doutor Duarte Guimarães, pelo apoio, orientação ao longo do desenvolvimento desta investigação e pelas correções que em muito enriqueceram as versões iniciais desta dissertação.

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À minha namorada Paola, por estar sempre presente e não me deixar desistir dos meus sonhos e objetivos, por mais complicados que eles pareçam a determinada altura.

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Por fim, gostaria de dedicar a mim mesmo esta pequena conquista, que pode ser o início de uma longa e brilhante carreira profissional.

RESUMO

O retratamento endodôntico é um procedimento clínico necessário nos casos de insucesso nos tratamentos do Sistema de canais radiculares de um elemento dentário. Consiste na remoção do material obdurador anterior do sistema de canais radiculares seguido de novo preparo químico-mecânico, desinfeção e obturação do sistema de canais radiculares. Quando usados em combinação com sistemas adequados de ampliação e iluminação, os insertos de ponta ultrassónica são uma ferramenta eficaz para a remoção de obstáculos endodônticos. Também são úteis para ativar soluções de irrigação, aumentando a sua eficácia na limpeza do sistema de canais radiculares. O objetivo deste trabalho é comparar a eficácia de instrumentos manuais com instrumentos ultrassónicos, podendo assim indicar em quais situações clínicas é possível utilizar as técnicas disponíveis. Esta revisão sistemática responde a uma estratégia PICO. As buscas foram feitas nas bases de dados *Pubmed*, *B-On*, Scielo, *Google Académico* e *Science Direct* utilizando as seguintes palavras-chave: Retratamento endodôntico, ultrassom, instrumentos manuais e com a aplicação de critérios de elegibilidade. Foram encontrados 11 estudos que avaliam a utilização do ultrassom na remoção da obturação remanescente. Os resultados desta revisão sistemática mostraram que nenhuma técnica consegue eliminar completamente a guta-percha e o cimento de preenchimento das paredes do canal radicular, especialmente quando o canal está achatado ou apresenta istmo, mas os ultrassons podem melhorar os resultados.

Keywords: Endodontic Retreatment; Endodontics; Endodontics Failures; Ultrasound

ABSTRACT

Endodontic retreatment is a necessary clinical procedure in cases of failure in treatment of root canal system in a dental element. It consists in removig the anterior obturate material from the root canal system followed by a new chemical-mechanical preparation, disinfection, and filling of the root canal system. When used combinated with suitable magnification and illumination systems, ultrasonic tip inserts are an effective tool for the removal of endodontic obstacles. They are also useful for activating irrigation solutions, increasing their effectiveness in cleaning the root canal system. The aim of this work is to compare the effectiveness of hand-held instruments with ultrasonic instruments, thus being able to indicate in which clinical situations it is possible to use the available techniques. This systematic review responds to a PICO strategy. Searches are made in databases Pubmed, B-On, Scielo, Google Scholar and Science direct using the following keywords: Endodontic retreatment, ultrasound, manual instruments and with the application of eligibly criteria. We found 11 studies that evaluate the ultrasound's utilization in removing the remanescent filler. The findings of this systematic review demonstrated that no method completely eradicate the gutta-percha and cement from the roots of the canal, especially when the canal is flatted or has a isthmus, but the ultrasound can improve the results.

Palavras-Chave: Endodontic Retreatment; Endodontics; Endodontics Failures; Ultrasound

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LIST OF ACRONYMS AND ABBREVIATIONS

CSI	Classic syringe-based irrigation
PUI	Passive Ultrasonic irrigation
PIPS	Photoinitiated photoacoustic streaming
RC	Root canals
RCS	Root canal system
UA	Ultrasonic activation

1. INTRODUCTION

Endodontics is a branch of Dentistry which is responsible for studying pulp and periapex pathologies and whose main objective is the preservation of teeth that were once considered lost (AAE, 2020).

The place where the dental pulp is lodged inside the tooth structure is called the root canal system (RCS). This system consists of two distinct areas, the pulp chamber and root canals (RC) (AAE, 2020).

1.1. Endodontic Retreatment

The retreatment of previously treated teeth is a difficulty that necessitates the remotion of the entire filled material and residual pulp that may be present in the RCS of the treated teeth. Several techniques may be indicated for the execution of this procedure (Soares et al., 2015).

In order to achieve success in endodontic re/treatments, it is necessary to have an effective identification of RC, their complete disinfection and filling (Li et al., 2013; Prada et al., 2019).

The term “retreatment” is defined as a procedure that involves the remotion of the filled material from RC, followed by cleaning, shapeing, and re-filling (AAE, 2020).

Causes that can lead to endodontic failure include: coronal infiltration, root fractures, errors in diameter, length and direction, canals no identified, small files, over extensions with under-filling, obstructions, rungs, perforations, fracture of instruments, surgical failures, non-identification and location of canals, and involvement of teeth with changes in the periodontium (Tabassum e Khan, 2016; Zanza, Reda and Testarelli, 2023).

1.1.1. Causes of failure in endodontic treatment

Anatomical causes:

Some of the features that are present in the pulp anatomy are: pulp horns, lateral and furcation accessory canals, canal orifices, apical deltas and apical foramina (Zanza, Reda and Testarelli, 2023).

It’s uncommon to observe a tooth with a straight RC and a round or rectangular shape, the majority of teeth have a degree of circularity or rectangularity, respectively. Additionally, the majority of channels have multiple levels of slope along their length.

However, existing curvatures can lead to some difficulty in the instrumentation, canal disinfection and three-dimensional filling (Sakkir et al., 2014).

Laceration is the degree of angulation or sharpness in the base or summit of a tooth that is formed. It is considered a mesial or distal tear when there is an angle of 90º or greater along the axis of the tooth or root. It can also be defined by a deviation of the apical part of the root when it forms an angle of 20º or higher (Sakkir et al., 2014).

Aberrant shape variations, in canal configuration, accessory canals, bifurcations, isthmuses, and anomastosis, are typically difficult to identify, creating a problem for endodontic treatment (Park, 2013; Peña-Bengoa et al., 2023).

Microbiological causes:

The joining of the microorganisms of the infected pulp with the cells of the host’s immune system slowly leads to a necrosis of the entire pulp system of the affected tooth, subsequently resulting in the development of periradicular diseases (Jain et al., 2015).

An infected RCS is either caused by carious exposition or trauma that cannot be removed by the host’s mechanisms of healing or in conjunction with antibiotic therapy that is systemically administered. As a result, there is a necessity to utilize on-site therapy, along with mechanical therapy that ischemic, both components are necessary for a successful outcome (Jain et al., 2015).

Different species of bacteria are able to colonize the RCS. However, Gram-negative bacteria, such as Enterococcus fecalis, Candida Albicans and Actinomyces are predominant in primary endodontic infection (Marinho et al., 2015; Prada et al., 2019).

Procedural Errors and Instrumentation Errors:

Endodontic treatment depends mainly on the creation of a correct access cavity and the identification of all roots, as well as the possibility of successful chemical-mechanical cleaning (Haji-Hassani et al., 2015).

The most common reason for the RCS to be contaminated by oral fluids and microorganisms after endodontic treatment is fractured teeth, microinfiltrations, or the loss of both temporary or permanent restorations. In addition, if the root system filling is not of sufficient quality, it can lead to the creation of infections (Rabihah e Saunders, 2014).

All the most frequent errors are organized as follows:

- Errors during the access cavity: Incorrect form; Location of the channels; Furcation drilling.
- Errors during preparation and cleaning: Step formation; Insufficient irrigation; Transportation of debris; Instrument fractures; Apical perforation; Under-instrumentation; Over-instrumentation/Apical Zip.
- Errors during channel filling: Under-Filling/Over-Filling; Sub-extension/Over-extension (Haji-Hassani et al, 2015).

Limitations of materials (irrigation and filling):

Systematic irrigation of the RCS is considered a key requirement for successful treatment. It is usually achieved through the combination of instrumentation and irrigation. Therefore, the result of an Endodontic Treatment depends not only on the mechanical instrumentation but also on the effectiveness of the irrigating substances. However, there are always microorganisms that remain in the RC, despite the cleaning and irrigation procedures. This is due to the different and complex morphologies that RC can adopt, where bacteria, necrotic tissue debris and garbage can be retained or accumulated (Alí et al., 2015).

1.1.2. Endodontic Retreatment Classification

Endodontic retreatment has two classifications: periradicular surgery or conventional retreatment, which can offer a good prognosis when well indicated. Conventional endodontic retreatment is done for RC (crown-apex) in teeth whose endodontic treatment is incomplete or stagnant by the clinician and whose primary endodontic therapy is complete but has poorly performed preparation and or filling (Torabinejad & White, 2016).

Periradicular surgery or paraendodontic surgery is the surgical access to the apical and periapical areas and is chosen when non-surgical retreatment is impossible or when the risk/benefit ratio of retreatment is greater than that of surgery (Jonasson & Ragnarsson, 2018).

1.1.3. Steps of conventional endodontic retreatment

Endodontic retreatment has several phases: preparation of the access cavity, identification of RC(s) holes that are missing, gaining access to the RC(s), followed by removing the

filling materials from the RCS and instrumentation, and decontamination of the RCS (Tandon et al., 2022).

Access Surgery

Root canal access surgery is the stage where coronary restorations are removed, which can be simple such as amalgams, composite resins or complex such as metal or ceramic crowns that sometimes serve as support for prosthetic work.

The sectioning of metal-ceramic or metallic crowns is one of the ways to remove them, where the external part, which is usually coated with ceramic, is worn with the use of diamond drills from the top of the tooth to the bottom of it and the metal part of the crown will be sectioned using a ball drill until it reaches the dentin. After the crown has been separated, a rigid metal instrument can be used to trace the section with a slight lever movement until the fragments are displaced (Kaur, Arora & Malhan, 2021).

Removal of intraradicular retainers

After primary endodontic treatment, most elements have an intraradicular retainer that will facilitate prosthetic reconstruction (da Costa et al., 2022; Lopes et al., 2015). To avoid accidents such as drilling and root fracture in an already weakened tooth, the dentist needs to perform the removal of the retainers in endodontic retreatment with special care and techniques (Lopes et al., 2015).

The literature suggests that mechanical pin removal systems can be efficient, especially in single-rooted and slightly flattened teeth in the mesiodistal direction (da Costa et al., 2022).

The purpose of using ultrasound for pin removal is to apply an ultrasonic vibration, in a short time, that generates mechanical impacts on the extra-radicular portion of the pin, leading to microfractures in the cement, allowing its removal easily by traction (Lopes et al., 2015). Ultrasound can act directly on the pin or, if the pin is secured, by hemostatic forceps on it (Lopes et al., 2015) To prevent overheating, water is used together with ultrasound.

Phase of remotion of the obturator material from the root canals

The main substances used in endodontic fillings are gutta-percha associated with cement. Several means for removing endodontic filling material, specifically gutta-percha, have been proposed, which include mechanical means such as endodontic instruments, thermal

means such as heated presser feet, special devices, chemical devices, organic solvents and thermomechanical and chemimechanic combinations (Gorduysus et al., 2017).

When the endodontic filling is compacted in the canal, gutta-percha removal can be initiated by using Gates-Glliden or Largo drills (sizes 1 -3) in the 2 mm cervical segment of the canal, where the friction of the instrument generates enough heat to plasticize the gutta (Kasam et al., 2016; Lopes et al., 2015). This step will facilitate access to the most interior portions of the canals and serve as a reservoir for the placement of the chemical solvent. (Kasam et al., 2016)

Chloroform is a more popular type of organic solvent because it solubilizes gutta-percha more efficiently, has a low cost, and has a more pleasant odor. (Kasam et al., 2016).

Due to the carcinogenic activity, some scientists have been researching new organic solvent alternatives. Eucalyptol is also toxic and removes gutta-percha less efficiently but Orange oil represents a good alternative in the dissolution of gutta, compared to other toxic solvents, as this oil has proven safety, is biocompatible and non-carcinogenic (Barreto et al., 2016)

In endodontic retreatment, the association of the solvent-instrument is one of the most commonly performed techniques to remove gutta-percha (Kaur, Arora & Malhan, 2021)

In addition, some mechanized endodontic instruments have been indicated for RC unfilling because they are faster than manual instruments. The rotary instruments plasticize the gutta-percha by frictional heat, work at low speeds with micro electric motor and are designed for materials to be removed in the apicocoronal direction. Have been developed specific instruments for retreatment, highlighting the ProTaper Universal Retreatment®(Maillefer, Switzerland), the Mtwo Retreatment® (VDW, Germany), D-Race® (FKG Dentaire, Switzerland) and R-Endo® (Lopes et al., 2015). Rotary instruments designed for retreatment have a tapered (pyramidal) cutting tip that facilitates the easy instrument’s movement in the channel filling material (Garg et al. 2015).

Some studies have shown that the use of the ultrasonic irrigation tip, which works through vibration passive, can decrease the extrusion of debris (Kasam & Mariswamy, 2016).

Endodontic reinstrumentation

To carry out a good cleaning and elimination or maximum reduction of bacteria from the channels during Endodontic retreatment, manual files, rotary files, or a combination of

both can be used through the crown-apex approach that enlarges the canal’s cervical and middle region before apical preparation, reducing the chances of debris extrusion via 6ltraso. The re-instrumentation of the channels can be done simultaneously with the emptying of the obturator material of the channels (Lopes et al., 2015).

Additionally, to the main filler removal technologies, there are proposed some complementary options to improve the cleaning and disinfection process, such as: Sonic motion, passive ultrasonic or laser activation, multi-sonic activation and additional endodontic instrumentation with XP Endo or self-adjusting files (Ajina, Shah and Chong, 2022; Baumeier et al., 2022).

Refilling of root canals:

The determination of the ideal apical limit for filling is a controversial issue in endodontics. The new endodontic filling needs to be homogeneous and inserted into the canal, 1 to 2 mm below the radiographic apex (Crozeta et al., 2020; Matoso et al., 2021).

Among the techniques for endodontic refilling, the techniques of manipulation of the gutta-percha cones at cold are used, such as lateral condensation and the one that promotes the heating of the gutta-percha, called thermoplastic (Kuçukekenci & Kuçukekenci, 2019; Matoso et al., 2021)

1.1.4. Non-surgical methods of endodontic retreatment and systems

In retreatment, eliminate the filling material from RC that was inadequately prepared is essential as this material causes a mechanical barrier that prevents the contact of irrigation solutions and intracanal dressings with the RC walls.

Manual Endodontic Instruments

6. Files H (Hedström): Hedström type files (or H-type files) are hand-held endodontic instruments manufactured from twisting the stem of pure stainless steel, resulting in a conical structure with longitudinal, spiral grooves. H files are Group I instruments according to ISO-FDI classification (Standart International Organization – Federation Dentaire International), which is based on the method of use (Garg and Garg, 2014b). As well as other steel files stainless steel, in some countries, Hedström files are single-use or Disposable.

Rotary Mechanized Instruments

The use of rotary systems to remove gutta-percha by non-surgical techniques has been indicated as a highly effective system (Colaço and Pai, 2015, Rodig et al. al., 2014). These instruments mechanically lacerate the gutta-percha and cement, and with the heat generated by friction, thermoplasticize the filling mass.

Recently, several rotary instruments manufactured in NiTi have been introduced to the market with varied design features, including cross-section, cutting angle, turns, helical angle, etc. (Guedes et al., 2015)

1. Gates-Glidden Drills: Gates-Glidden (GG) drills are Group III instruments, according to the ISO-FDI classification, based on the method of use (Garg and Garg, 2014b). They are elliptical in shape, available in lengths of 15 and 19 mm or shorter for posterior teeth, and are instruments used to open the entrance or access hole to the canal.
2. Peeso Drills: Like the Gates-Glidden drills, the Peeso drills are classified in Group III instruments, according to ISO-FDI classification (Garg and Garg, 2014b). Peeso drills and Gates-Glidden drills are aggressive cutting instruments that can quickly widen the canal, and the clinician should use them with extreme caution and at low speed (Garg and Garg, 2014b).
3. ProTaper® Retreatment: In 2006, Dentsply® developed the ProTaper® Universal system (Dentsply Maillefer, Ballaigues, Switzerland), introducing the ProTaper® Universal version Retreatment consisting of three files (D1, D2 and D3), which can be used at 500 to 700 rpm, and whose purpose is to unblock a previously treated channel (Garg and Garg, 2014a).
4. Mtwo®: The Mtwo retreatment system consist of two instruments with an active cutting tip, and is classified as mechanized instrumentation with continuous rotation (Yadav et al., 2013; Alves et al., 2014).

Reciprocating Mechanized Instruments (Reciproc)

Reciprocating systems are single-use instruments, which prevent metal weakening associated with prolonged clinical use and clinical fatigue (Dagna et al., 2014). This characteristic confers some advantages to these systems, as indicated by van der Vyver and Jonker (2014): lower fatigue and fracture, elimination of cross-contamination and sterilization procedures.

The use of reciprocating instrumentation has become more frequent with the development of systems like Reciproc (RCP) and WaveOne (Ramazani et al., 2016, Dincer et al., 2015)

1.2. Ultrasounds

Ultrasound is a sinusoidal mechanical wave that propagates in the same direction than the vibration and whose frequency is greater than 20KHz (da Costa et al., 2022).

The ultrasonic wave is a pressure variation that propagates through a medium elastic. Its propagation requires being in a material environment, unlike the electromagnetic wave that can propagate in a vacuum.

1.2.1. The Biological Effects of Ultrasound

Ultrasonic waves propagate in biological tissues, thus prolonging the physical action of the inserts and causing different mechanical effects: changes in pressure, tension, shear stresses, expansion, compression, velocity and acceleration in the environments traversed (da Costa et al., 2022).

In absorbent media, such as teeth and periodontium, the mechanical energy of ultrasound is converted into heat, whereas in an aqueous medium (a fluid or irrigation) ultrasound causes cavitation phenomena and local microcurrents. Thermal effects are related to the exposure time of the ultrasonic beam while cavitation is related to positive and negative sound pressure peaks (Zanza, Reda and Testarelli, 2023).

Thermal effects:

A good cooling system is essential to regulate the temperature. It will be different depending on the ultrasonic system used. A magnetostrictive unit requires irrigation of the handpiece and the insert, so the cooling system will pass through the handpiece and then to the insert. The water used for cooling heats up as it travels through the handpiece. When it arrives at the insert, it will be lukewarm; A higher irrigation flow will therefore be required to achieve more efficient cooling. On the other hand, piezoelectric units and sonic scalers only require cooling of the inserts. As a result, a lower irrigation rate will be required (Gupta et al., 2021).

1.2.2. Ultrasounds in Endodontics

The first application of ultrasound in endodontics was performed by Rickman in 1957. The equipment used was periodontal prophylaxis (Cavitron-Dentsply®), in which a specific tip (PR30) was adapted for endodontic purposes, acting as an auxiliary element of the RC instrumentation. However, due to the absence of irrigation during its operation, there was overheating, which resulted in the disuse of this equipment (Lira et al., 2017).

In endodontics, ultrasound can be applied, in conjunction with other techniques, for the removal of pulp nodules, removal of fractured metal pins, in the intensification of the action of irrigating solutions, in the placement of mineral trioxide aggregate (MTA) and in the treatment of calcified canals (Cruz & Salomão, 2020).

Therefore, ultrasound is applied in several procedures within endodontics, such as endodontic retreatment, deobturation, to gain access to RC, endodontic surgery, canal irrigation, among others (Lira et al., 2017).

Like any other procedure, ultrasound has its disadvantages, one of them being the heat it generates, which can damage periodontal tissue (Zanza, Reda and Testarelli, 2023).

The ultrasonic instruments that are utilized in dentistry included various types of tips that have different configurations, lengths, and shapes. Additionally, the frequency and amplitude of vibration can be optimized for each type of tip. Ultrasonics’ small size enables them to have a greater field of vision than other instruments that rotate, this is beneficial for precision cutting (Landolo et al., 2015). Just like teeth, ultrasonic tips have specific functions. There are currently two types of tips, smooth and diamond. The smooth is used when it is desired to perform less wear on the treated area, performing a more conservative treatment. Diamond metal, on the other hand, has a greater and more effective cutting power, being used when it is necessary to open a larger area, such as, for example, in the location of channels (Landolo et al., 2015). Because they are non-rotatable, ultrasonic tips provide greater stability for the operator, as well as greater safety for the patient, while also increasing cutting efficiency (Cruz & Salomão, 2020).

Objective

The objective of this systematic review is to compare the effectiveness of hand-held instruments with ultrasonic instruments, thus being able to indicate in wich clinical situations it is possible to use the 9ltrasoun techniques. The aim was also to map the number and methodology of the studies found.

2. DEVELOPMENT

2.1 Metodology

- **Sources of information and research**

For the elaboration of this systematic review, the PICO criteria (population, intervention, comparison and outcome) were considered.

Table 1. *PICO criteria*

Population (P)	Failure of endodontic treatment
Intervention (I)	Endodontic retreatment with ultrasound
Comparison (C)	Manual systems or ultrasound
Outcome (O)	Evaluate the differences between the two methodologies

- **Search question and methods**

The search question applied to this work was: “What are the differences between endodontic retreatment with ultrasound and manual instruments?”

For the elaboration of this work was conducted in November 2023 and April 2024, a bibliographic search strategy identified in vitro, in vivo, editorial and published in the last 10 years was carried out in the databases Pubmed, B-on, Google Scholar, Scielo and Science Direct, using the following keywords in multiple combinations, using the Boolean operator “AND/OR”: *“Endodontic Retreatment”*, “*endodontic failure*”, “*active point*s”, “*manual instruments*”, *“11ltrasound”*, *“irrigation”.*

- **Eligibility Criteria**

Inclusion and exclusion criteria were employed in the articles selection.

The following inclusion criteria are listed:

(6) Language: English, Portuguese and Italian; (2) Time Limit: articles published between 2013 and 2023; (3) Typology of the scientific article: case reports, clinical trials, comparative studies, control clinical trials, randomized clinical trials; (4) Made in humans; (5) Open access articles with abstracts available.

The following exclusion criteria are listed:

(6) Studies not related to endodontic retreatment; (2) Published before 2013; (3) Performed in vitro, animal or secondary; (4) Studies whose language is not English, Portuguese or Italian.

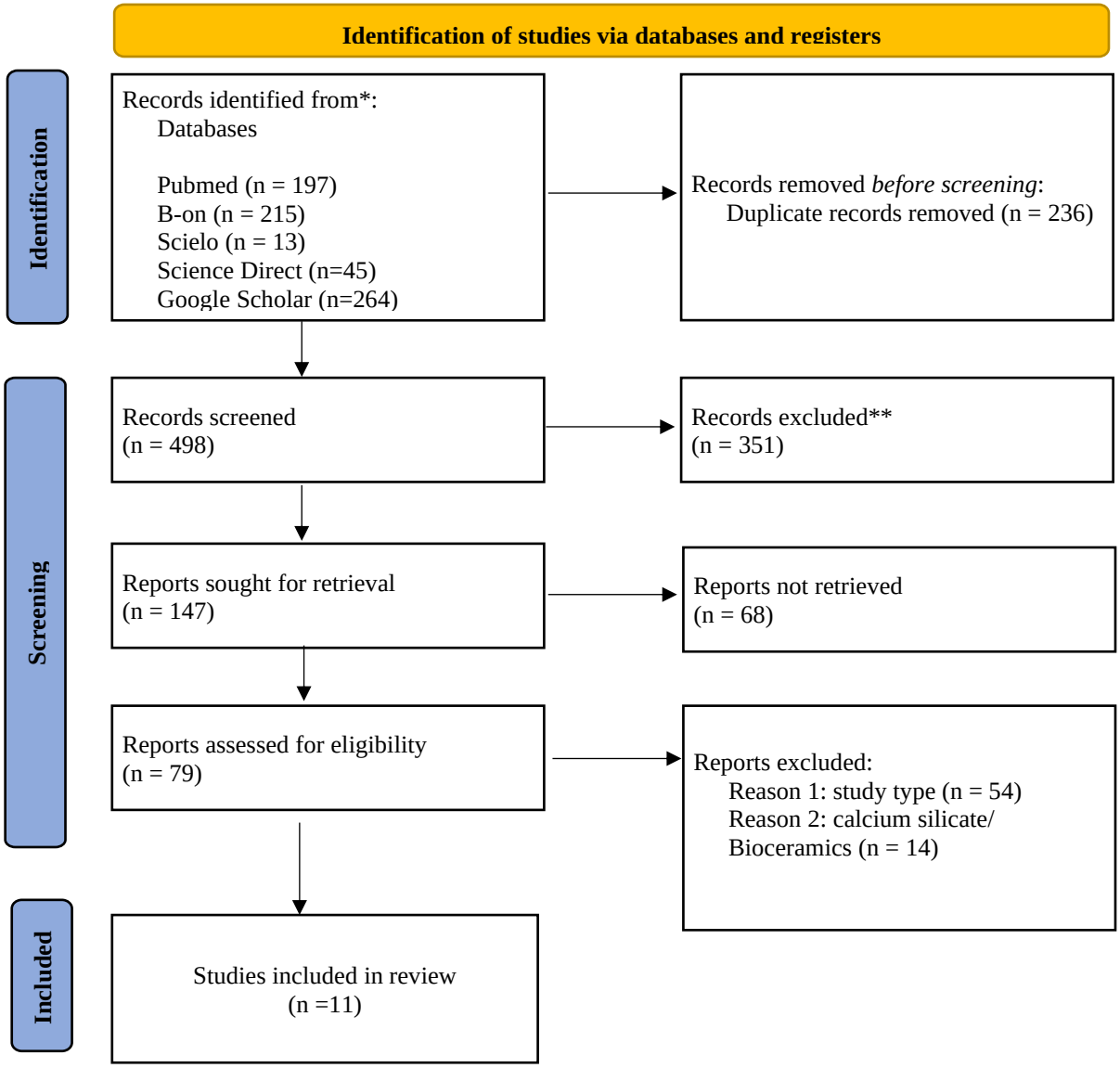
- **Study selection and Flow Diagram**

This research resulted in a total of 498 articles that were selected first by the titles, then by reading the abstracts and, finally, by the article in its entirety. Of these, 11 articles were selected for the results, because they are similar to each other.

To complement the introduction of this systematic review, other review articles are included and in reference websites on the subjects covered.

This methodology is described in the PRISMA diagram (Figure 1).

Figure 1. *PRISMA flow diagram for searches of databases*



- **Characteristics of the studies that are included**

The detailed methodologies and description of the 11 included publications in the present systematic review are summarized in Table 2, 3 and 4.

Table 2. *Characteristics of the included studies*

Study/ Year	Study design	Objective	Sample size	preservation after extraction
Peña-Bengoa et al., 2023	Comparative study	Investigate and assess the effects of ultrasonic activation (UA) on the tubular advancement of Bio-C Temp and UltraCal XS	single-rooted human premolars	0.9% saline solution
Martins et al., 2023	Ex vivo	Review the AH Plus sealer’s ability to penetrate in dentinal tubules following a RC retreatment	32 mandibular premolars	Not reported
Kaloustian et al., 2022	In vitro	Review the efficacy of the Endostar Revision system to eliminate remnants of filler material from RC that are ovally shaped using sonic irrigation as a supplement to cleaning.	30 extracted mandibular premolars	0.1% formocresol
Yang et al., 2021	In vitro	Review the effectiveness of laser-activated and UA methods in vivo for the eradication of iRoot SP and gutta-percha.	36 extracted single-rooted teeth	0.5% chloramine-T solution
Matoso et al., 2021	In vitro	Evaluate the capacity of the XP-endo Finisher R to eliminate remnants of filler material from the curved canals from maxillary molars, using the passive technique of ultrasonic irrigation (PUI) as a counterpart	24 mesiobuccal roots from maxillary first molars	Not reported
Crozeta et al., 2020	In vitro	Review the effectiveness of passive ultrasonic irrigation (PUI) and the GentleWave system as additional methods for to eliminate remnants of filler material from RC in an oval shape	20 distal roots from human mandibular molars	Not reported
Ferreira et al., 2020	In vitro	Review the effectiveness of sonic vibrations of a mixture of solvents that is binary (methyl ethyl ketone/ tetrachloroethylene) in regards to eliminate remnants of material that was filled	24 mandibular incisors	Not reported
Kuçukekenci & Kuçukekenci, 2019	In vitro	Contrast the effectiveness of irrigants based on various methods of activation with the bond strength of push-out fibers to RC	48 decoronated canines	0.1% thymol
Rivera-Peña et al., 2018	In vitro	Review the efficacy of a new ultrasonic tip as a supplement to the removal of filling material from flatted/ovalized spaces	45 mandibular incisors	Not reported
Kaloustian et al., 2018	In vitro	Compare the efficacy of Reciproc’s R25 treatment method to the TS2 method in elimination of GP and sealer from the mesial canals of the mandibular molars	44 extracted mandibular molars	0.1% formocresol
Bueno et al., 2017	Comparative study	Contrast the effectiveness of PUI in removing the filling material in root canals after using the WaveOne, Reciproc or ProTaper Universal	120 extracted maxillary incisors	0.1% thymol solution

Table 3. *Methodologic characteristics during endodontic treatment of the included studies*

Study/ Year	Endodontic Treatment		
	Instrumentation	Irrigation	RC Filling
Peña-Bengoa et al., 2023	WaveOne Gold system	20 Ml of 2.5% sodium hypochlorite (NaOCl); 5 Ml of EDTA 17% for 3 min, followed by 5 Ml of 2.5% NaOCl	Not reported
Martins et al., 2023	F4 ProTaper Universal instrument	20Ml of NaOCl, PUI with 1 Ml of 17% EDTA for 1 min.	single cone technique
Kaloustian et al., 2022	ProTaper Gold	3 Ml of 6% NaOCl; 3 Ml of 17% EDTA, 5 Ml of distilled water and 3 Ml of 6% NaOCl	pulp canal sealer EWT with continuous wave vertical compaction technique
Yang et al., 2021	ProTaper Next rotary instruments	2 Ml 17% EDTA for 1 min, after 2 Ml of 2.5% NaOCl for 1 min and 2 Ml of saline solution for 1 min	single-cone technique with iRoot SP and gutta-percha
Matoso et al., 2021	Wave One Gold	2.5% NaOCl, 17% EDTA and distilled water	AH Plus Sealer using the lateral compaction filling technique
Crozeta et al., 2020	R40 (40.06) instrument	3 Ml of 6% sodium hypochlorite (NaOCl); 3 Ml of 17% EDTA, 5 Ml of distilled water and 3 Ml of 6% NaOCl	gutta-percha and AH Plus sealer using warm vertical obturation
Ferreira et al., 2020	ProTaper Next (X1, X2)	2 Ml of 3% NaOCl followed by 2 Ml of 17% EDTA for 1 min, sonically agitated for 1 min with EndoActivator and 1 Ml of distilled water.	Single-cone technique and AH Plus sealer
Kuçukekenci & Kuçukekenci, 2019	RECIPROC system	5 Ml of 5.25% NaOCl, 5 Ml of 17% EDTA, and 5 Ml of destiled water	gutta-percha cone and AH Plus sealer with use of the cold lateral compaction technique
Rivera-Peña et al., 2018	15 K-file, Flatsonic (Helse Ultrasonic, Santa Rosa do Viterbo, Brazil)	2 Ml of 2.5% NaOCl, ultrasonically activated, 17% EDTA for 3 min and ultrasonically activated for 60s, 2 Ml of 2.5% NaOCl and ultrasonically activated three times for 20s	continuous wave of condensation technique with gutta-percha
Kaloustian et al., 2018	ProTaper Gold rotary system	3 Ml 6% NaOCl, 3 Ml 17% EDTA, followed by 3 Ml 6% NaOCl	pulp canal sealer EWT and the continuous wave vertical compaction technique
Bueno et al., 2017	ProTaper Rotary system	5 Ml 17% EDTA for 3 min and 5 Ml 2.5% NaOCl	gutta-percha cones and AH Plus Sealer with continuous wave of condensation technique

Table 4. *Methodologic characteristics of ultrasounds in the included studies*

Study/ Year	Sample Groups	Ultrasonic instrument	Method	Method Validation	Results
Peña-Bengoa et al., 2023	Bio-C Temp, Bio-C Temp+UA, UltraCal XS, UltraCal XS+UA	E1 Irrisonic ultrasonic tip (Helse Ultrasonics, Santa Rosa de Viterbo, Brazil) for ultrasonic activation	Tubular penetration of intracanal medications in middle and apical thirds of the canals	Confocal laser scanning microscopy (CLSM)	UA increases the tubular depth (both volume and area) of Bio-C Temp at the third apical position, but it has no significant effect on Ultracal XS.
Martins et al., 2023	Reciproc R40 + ultrasonic activation (RU); Reciproc R40 + sonic agitation (RS); ProTaper Next (X4) + ultrasonic activation (PTNU); ProTaper Next (X4) + sonic activation (PTNS)	E1-Irrisonic (Helse Dental Technology, Santa Rosa de Viterbo-SP, Brazil)	sealer penetration	CLSM	The re-treatment with ProTaper Next demonstrated a significant increase in the volume of AH Plus sealer that reached the dentinal tubules in the apical third. The additional cleaning didn’t have a positive effect on the removal of the material that was filleded.
Kaloustian et al., 2022	Group 1: Revision + EQ-S sonic activation Group 2: Revision	EQ-S cordless sonic endo irrigator coupled with the 25/02 tip	final volume of the remaining filling material	Digital microscopy	The technique of retreating using sonic activation was found to have a lower degree of residual material filled than the technique of retreating using irrigants without activation at the coronal third, but no significant difference was observed between the two groups at the apical or middle thirds
Yang et al., 2021	Group 1: classic syringe-based irrigation (CSI). Group 2: passive ultrasonic irrigation (PUI). Group 3: photon-initiated photoacoustic streaming (PIPS)	K-type noncutting ultrasonic size 15 tip (Satelec Acteon, Mérignac, France)	removed volume for the filling materials	Micro-CT and SEM	Compared to PUI and CSI, the use of PIPS increased the effectiveness of the removal of the remaining iRoot SP and gutta-percha
Matoso et al., 2021	XP-endo Finisher R group PUI group	E1-Irrisonic ultrasonic tip (Helse Dental Technology, Santa Rosa de Viterbo, Brazil)	final volume of the remaining filling material	Micro-CT	The percentage of material reduction was greater for the XP-endo Finisher R than for the PUI ($p = 0.0195$)

Study/ Year	Sample Groups	Ultrasonic instrument	Method	Method Validation	Results
Crozeta et al., 2020	Group 1: PUI (n=10) Group 2: Gentle Wave (n=10)	PUI	volume of remaining filling material in the three thirds	Micro-CT	PUI had a greater success rate by removing18% of the remaining filler material, whereas the GentleWave system had a 10% success rate.
Ferreira et al., 2020	Group 1: ProTaper Next X3 file Group 2: ProTaper Next X3 and X4 files	EndoActivator for sonic agitation of a mixture of solvents	volume of RC filling remnants in apical portion	Micro-CT	Another procedure with a two-solvent solution that was potentiated by EndoActivator demonstrated to be very effective in the apical canals of the mandibular incisors
Kuçukekenci & Kuçukekenci, 2019	Control group NaOCl + EDTA group PUI group LAI group	ultrasonic system handpiece equipped with a size 25 IRRI S smooth wire	push-out test in the three thirds.	Universal testing machine (Autograph AGS X; Shimadzu Co, Japan)	The bond strength of the groups was: Control (10.04 Mpa), NaOCl+EDTA (11.07 Mpa), PUI (11.85 Mpa), and LAI (11.63 Mpa))
Rivera-Peña et al., 2018	Group RE: Reciproc R25/.08, Group REC: Reciproc R25/.08 + Clearsonic tip, Group CRE: Clearsonic tip + Reciproc R25/.08	ultrasonic tip with an arrow-shaped design R1 Clearsonic	percentage of residual RC filled material	Micro-CT	The lowest percentage of residual canal filling material was recorded in Group CRE. The utilization of the ClearSonic tip followed by the Reciproc 25/.08 file to eliminate filled material from the RC led to the lowest percentage of remaining debris in the entire RC and in the apical third.
Kaloustian et al., 2018	Group A: 2Shape + Endo Ultra Group B: 2Shape +Irrisafe Group C: Reciproc + Endo Ultra Group D: Reciproc + Irrisafe	Irrisafe (Satelec Acteon Group, Merignac, France) Endo Ultra (Vista Dental Products, Racine, WI, USA)	volume and percentage of the filled material remaining in the three thirds	Micro-CT	The supplemental PUI increased the effectiveness of removing the filled material and wasn't no significant difference between the four groups.
Bueno et al., 2017	Group R: Reciproc R25; Group W: WaveOne; Group PT: ProTaper Universal; Group R-PUI: Reciproc R25 + PUI; Group W-PUI, WaveOne + PUI Group PT-PUI: ProTaper Universal + PUI	MTS Ultrasonic Obtura Spartan system (Obtura Spartan Endodontics, Algonquin, IL)	total canal space and remaining material	Digital camera	The utilization of PUI did not have a positive effect on the elimination of the filled material from the RC, regardless of the previously employed instrumentation method.

2.2 Results

The study of Peña-Bengoa et al. (2023) intended to assess the capacity of ultrasonic activation (UA) to facilitate the entrance of tubular components in comparison to Ultracal XS and Bio-C Temp. 40 human premolars with single roots were endodontically prepared, and these were divided in four experimental groups (n=10). All medication were combined with a specific calcium indicator (Fluo-3) and simplyjected into the canals without being active. The samples were sealed at the RC entrance with glass that isomerizes to acrylic, these were placed in transparent acrylic cuboids. The samples were held for 7 days. For each tooth, 1 mm thick slices were isolated from the middle and apical thirds of the RC and the samples were observed by CLSM and the volume and area of contact were recorded for each group. There was a minor increase in the maximum depth of penetration following the application of ultrasonic activation in all groups (except for Ultracal XS at the third tier), but the changes were not significant for either of the medications. However, when analyzing both treatments at the third apical position after UA, Bio-C Temp+UA had a significantly greater maximum depth of penetration than UltraCal XS+UA. No significant differences were observed when comparing the two treatments without using ultrasonic technology, neither at the middle nor at the apical third. UA increased the volume of Bio-C Temp that was penetrated into the thirds of the medial and the apical portion, but the increase was only significant at the apical portion. UA increased the area of contact of UltraCal XS in the thirds of the medial and apical side, but the changes were not significant on a statistical level. The volume of the area that was penetrated by Bio-C Temp+UA was significantly greater than the volume of the area that was penetrated by UltraCal XS+UA, both in the middle and at the apical thirds.

The investigation of Martins et al. (2022) intended to assess the effectiveness of the AH Plus sealer in entering dentinal tubules following RC treatment followed by two additional cleaning methods. 32 mandibular premolars with single canals were instrumented and filled by a single cone method with the addition of Rhodamine B to the sealer Endofill®. Before that, the teeth were randomly assigned to four groups (n=8) according to the methods used for repairs and additional cleaning. A new root canal filling style was employed using the System B technique, the AH Plus sealer was combined with a Fluorescein colorant. The roots were divided into 3, 5 and 7 mm sections from the apex, and these sections were evaluated by a confocal laser microscope using the method of epifluorescence with a combination of rhodamine B and fluorescein as the absorption and

emission wavelengths. In the images that were obtained, the degree to which the sealer entered the dentinal tubules was assessed.

The results of this investigation demonstrate that the apical third has a greater capacity forAH Plus, because ProTaper Next demonstrated a greater propensity to remove fill dirt, this may be attributed to their specific design that is rectangular in shape and moves towards the apex. Its design allows the instrument to only interact with the wall in two specific locations, this results in a larger area of the escape of the sealer material. Despite both instruments having the same apex and a similar taper, it appears that the design of the instrument is more likely to have a better effect on the apical third (3mm). There is no significant difference in the statistical distribution after the additional cleaning of the root canals using sonic or ultrasonic irrigation, the three thirds of the distribution are still distinguishable. They concluded that the re-treatment with ProTaper Next had a significantly greater degree of dentinal tubule penetrability in the apical third of the dentine regardless of the additional cleaning procedure. The additional methods of cleaning were equivalent and did not have a positive impact on removing the material filled in all of the thirds that were examined (Martins et al., 2022).

The investigation of Kaloustian et al. (2022) sought to assess the effectiveness of the Endostar Revision® system (Poldent, Warsaw, Poland) in removing the material filled from an oval-shaped RC via sonic irrigation as a supplement to cleaning. 30 human-d extracted mandibular premolars with an ovoid shape of RC were instrumented using the ProTaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland) that was filled by the continuous wave vertical compaction technique using a pulp sealer named EWT (Sybron Dental Specialties, Orange, CA, USA). The teeth were randomly assigned to either of two groups (n = 15) based on the type of instrumentation and the extra cleaning method. The technique of retreating using activators for the endodontic irrigants had a lower percentage of residual filling material than the technique of retreating using irrigants that lacked activators at the coronal third. No significant difference was observed between the apical third and the middle third of the coronal region for either group ($p > 0.05$). The middle third of each group had a lower percentage of residual filling material than the coronal.

The results demonstrate that the Revision system alone, or in conjunction with Sonic Irrigation, failed to reduce the amount of filling material in the RC to zero. However, the Revision system exhibited a curious result in removing filler materials without the use of

sonic equipment, with 14.02% remnants in the apical third, 8.66% in the middle third, and 19.17% in the coronal third. The results of this investigation indicate that the Revision system associated with sonic irrigation using EQ-S has the potential to enhance the removal of filling materials from the coronal third compared to the Revision system associated with irrigation by needles (Kaloustian et al., 2022).

The study of Yang et al (2021) intended to assess the effectiveness of laser-activated and ultrasonic-activated methods in vitro for the remotion of the tricalcium silicate-based sealer iRoot SP®(FKG, La Chaux-de-Fonds, Switzerland) and the gutta-percha following standard canal cleaning procedures with the utilization of NiTi rotary instruments. 36 teeth that were extracted as single roots were filled with a single-cone method using the GP and iRoot SP sealer. These root canals were subsequently retreated using the ProTaper Universal system. The samples were segregated in three groups based on the final method of irrigation in repairs procedures: group 1, classic syringe-based irrigation (CSI); group 2, passive ultrasonic irrigation (PUI); and group 3, photons-activated photoacoustic streaming (PIPS). All of the groups had remnants of root material in the RC that was mechanically replenished. The additional utilization of PIPS led to a significantly greater volume of root material than the PUI and CSI methods. The SEM scores were significantly lower in the PIPS group than in the PUI and CSI groups, especially in the middle and apical thirds.

The investigation of Matoso et al. (2021) intended to assess the capacity of the XP-endo Finisher R® (FKG, La Chaux-de-Fonds, Switzerland) to eliminate remnants of filling material from the curved mesiobuccal region of the maxillary molars, using the PUI method as a counterpart. 24 main mesiobuccal canals (MB1) of the maxillary molars were instrumented and obtured with gutta-percha points and AH Plus Sealer (Dentsply Sirona Endodontics, Ballaigues, Switzerland). Samples were then retreated with a standardized protocol that included Wave One (#35/06) as the master apical reference. Micro-CT scans recorded the volume of the remaining filler material (in mm^3). Samples were segregated into two groups (n = 12) based on the supplementary cleaning method used: (PUI) or XP-endo Finer R. The mean volume of the baseline, the final volume, and the percentage of reduction (%) of the filler material for XP-endo Finisher R and PUI were respectively: 0.060 mm^3, 0.042 mm^3, and 31.280%, and 0.064 mm^3, 0.054 mm^3, and 16.575%. Both protocols tested decreased the volume of filler material ($p < 0.05$). The percentage of reduction was greater for the XP-endo Finisher R than for the PUI ($p < 0.05$). They

concluded that the protocol used in conjunction with the retreatment procedure had a positive effect on the elimination of the root material in curving canals, but the protocol was approximately twice as effective as the retreatment procedure.

The investigation of Crozeta et al. (2020) sought to assess the effectiveness of passive ultrasonic irrigation (PUI) and the GentleWave ® system as a supplement to the removal of remaining fill dirt from an oval-shaped RC. 20 distal roots of human mandibular molars with a single, ovoid-shapedRC, were formed with the R40 instrument and obtured with gutta-percha and AH Plus sealer using a warm vertical obturation. The initial procedure for removing the material that was filled was performed with the R50 instrument, followed using the PUI (n = 10) or the GentleWave system (n = 10). Micro-CT scans were acquired following the filling process, the initial removal of material, and following the use of PUI and GentleWave. The amount of remaining filler material that was left over was estimated for the entire RC as well as for the three thirds. The utilization of PUI and Gentle Wave as additional methods significantly decreased the amount of remaining filler material following the initial instrumentation (P <.05). However, none of these methods successfully rendered canals devoid of filler materials. PUI had a greater success rate by reducing the amount of the remaining filler material in 18%, while the GentleWave system had 10%.

The investigation of Ferreira et al (2020) intended to assess the efficacy of sonic vibrations of a mixture of solvents (1:1) regarding the removal of material remnants and compare the effects of the additional solvent vibrations to the next larger size of instrument. Teeth were assigned to two different groups of 12 specimens and prepared according to the same protocol employed in the canals instrumentation and a final irrigation was performed with 2 Ml of 3% NaOCl, followed by 2 Ml of 17% EDTA, both of which were activated with EndoActivator for 1 min. All samples were subjected to a supplementary procedure that involved using a 1:1 ratio of solvents – MEK/ tetrachloroethylene (sonicated). Each canal was filled with 1 ml of the mixture of solvents sonically agitated for 5 minutes using the EndoActivator. The amount of filling material was determined through micro-CT in the top 5 mm.

A significant decrease in the amount of filler material that was re-used after preparation was observed in both groups for both regions assessed. Group 1 had more remnants than Group 2, both for the sections and the full apical canal, there wasn’t difference between the two groups that was statistically significant (p = 0.200 for 1–3 mm; p = 0.136 for 3–

5 mm; p = 0.087 for 1–5 mm). Also, there were no significant differences between Group 1 and 2 following the use of the solvent (p = 0.974 for 1–3 mm; p = 0.622 for 3–5 mm; p = 0.412 for 1–5 mm). However, both groups demonstrated a significant difference ($p < 0.05$) in the amount of remnants from previous preparation (up to X3 or X4) in comparison to after solvent exposure. As a result, the additional procedure with the utilization of the solvent mixture was beneficial in both groups. They’ve come to the conclusion that a non-traditional mixture of solvents – MEK/1 tetrachloroethylene (1:1) – which is potentiated by sonic action is capable of becoming a supplemental and final step in the process of removing the obturation. It could be combined with a single solution that had both a dual purpose of dissolving gutta-percha and a resinous sealer. The strategy proposed would allow for the optimization of treatment methods to get a more refined RC without additional expansion (Ferreira et al., 2020).

The objective of the research of Rivera-Peña et al. (2018) was to assess the value of novel ultrasonic tips as a supplement to the rotary method of preparing flat/oval-shaped RC. 45 mandibular incisors were chosen and divided in three experimental groups (n = 15). The teeth were analyzed preoperatively and postoperatively using micro-CT and the quantity of residual filler material from the experimental groups was scrutinized. Group R had the greatest percentage of remaining RC material (76%), in comparison with groups REC (24%) and CREC (16%). The lowest percentage of residual canal filling material was recorded in group REC. About the percentage of residuals in the top third of the root canal, a significant difference was found when group R and group REC were contrasted with group CREC. Reciproc R25/ .08 alone was not significant in reducing the amount of filling material that was left over.

The purpose of the study of Küçükekenci & Küçükekenci (2019) is to assess the effectiveness of different methods of irrigation in conjunction with different amounts of irrigation fluid to the bond strength of post to the RC wall luted with self-adhesive resin cement (SARC). 48 human canines were employed and were divided in four groups that corresponded with the procedure of the post-space irrigation process and were treated. The bond strength of the groups was: Control (10.04 Mpa), NaOCl+EDTA (11.07 Mpa), PUI (11.85 Mpa), and LAI (11.63 Mpa). The differences observed among the groups aren’t significant ($p>0.05$).

The objective of the research of Kaloustian et al (2018) is to assess the effectiveness of the Reciproc R25 treatment method compared to the TS2® method in eliminate gutta

Percha (GP) and sealer from the RC of the mandibular molars. They attempted to assess whether the additional utilization of the Irrisafe and Endo Ultra PUIs increased the hygienic quality, or if the two types of PUIs had a different composition. The mesial canals from 44 mandibular molars were created and filled and the teeth were randomly divided in two groups, then one group was treated with Reciproc R25 (VDW, Munich, Germany) (n = 44) while the other group was treated with 2Shape (TS, Micro Mega, Besançon, France) (n = 44). A micro-CT scan was conducted before and after the repairs to assess the amount of remaining material filled. The teeth were then assigned to four different groups in order to test two different PUI devices: Irrisafe® (Satelec Acteon Group, Merignac, France) and Endo Ultra® (Vista Dental Products, Racine, WI, USA). A third micro-CT image was taken following the treatment to assess the effectiveness of the PUIs. The percentage of GP and the sealer that was removed was 94.75% for TS2 ($p<0.001$) and 89.3% for R25 ($p<0.001$). The PUI increased the effectiveness of the filling material removal by 0.76% for Group A, 1.47% for Group B, 2.61% for Group C and by 1.66% for Group D.

The study of Bueno et al. (2017) assess the effectiveness of PUI in the removal of the filling material for RC from teeth that have undergone endodontics, the use of a reciprocating system, Reciproc (VDW, Munich, Germany) or WaveONE (Dentsply Maillefer, Ballaigues, Switzerland), or a system that uses nickel-titanium (NiTi) as its sole component, ProTaper Universal Retreatment (Dentsply Maillefer). They use 120 straight canals of human maxillary incisors that were prepared and then filled. The samples were divided in six groups (n=20): Group R, Group W, Group PT, Group R-PUI, Group W-PUI, and Group PT-PUI. After removing the filler material, the teeth were longitudinally cut and photographed and the total amount of canal space and remaining material was estimated with the help of software that facilitates imaging. Remnants of the RC filler material were observed in all the teeth, regardless of the method of eliminate the filling. The average amount of residual filler material in the groups was 4.3 %, 2.8 %, 3.1 %, 3.2 % and 3.3 %, respectively. No statistically significant difference ($P>0.05$) was observed between the groups.

2.3 Discussion

An infected RCS may originate from caries or trauma and cannot be eliminated by the host or by systemic antibiotic therapy, requiring local therapy in conjunction with mechanical or chemical-mechanical therapy (Jain et al., 2015).

The goal of endodontic retreatment is the total elimination of the filled material and the cement associated with it, in order to recover access and patency to the apical foramen to carry out an effective cleaning and conformation of the RCS and to allow their disinfection, in order to facilitate the restoration of the periapical tissues (Bernardes et al., 2016).

The partial removal of the filling materials can serve as a mechanical barrier that prevents the interaction of solutions intended for irrigation and intracanalar drugs with the walls of the RC and the microorganisms that persist therein, and consequently influence the results of retreatment.

For this purpose, all full-text papers and articles published in the last ten years (2014-2024 years), mostly in English, containing the scientific evidence on to compare the effectiveness of hand-held instruments with ultrasonic instruments, thus being able to indicate in which clinical situations it is possible to use the available techniques and subjects related to dentistry profession such as, epidemiological data, safety, environment, and marketing related to its use, were collected. All methodology types of studies were included, from epidemiological surveys, randomized clinical trials, in-vitro/experimental and in-situ studies, narrative reviews, systematic reviews, case reports and editorials.

The endodontic treatment failure, as the first topic of this s review, is not evaluate because all the samples in the various studies are from extracted teeth. The studies are heterogeneous, using molars, canines and incisives.

The second topic of this systematic review concerned intervention Endodontic retreatment with ultrasound. In this systematic review we evaluate the potencial of ultrasonic devices on removing the filling material, comparing with other devices.

In Endodontic retreatment other protocols have been proposed that would be employed after the remotion of the filling material and repairs of the RC by means of a mechanized System. These protocols suggest the use of sonic and ultrasonic inserts, special

instruments with the purpose of enhancing cleaning such as SAF® (Self adjusted file), XP-endo Finisher and XP-endo Finisher R, among others (Martins et al., 2017).

The efficacy of sonic activation is attributed to the acoustic pressure within the irrigating fluid, which is generated by the oscillating blade. These fields of flow produce a hydrodynamic force that acts on the instruments along the sonic axis. The transmission rate is dependent on the operating conditions, such as the power level, even when the tip of the insert is stuck in the channel’s light, transmission still occurs along the instrument (Kaloustian et al., 2019).

New inserts have been developed to aid in endodontic retreatment, such as R1 Clearsonic (Helse Ultrasonic, Santa Rosa de Viterbo, Brazil), which has an arrow shape and has been proposed to improve the removal of remnants of obturator material from flattened or oval channels. Rivera-Peña *et al.* (2018) studied the influence of this ultrasonic insert as a complementary method in retreatment, using teeth with flattened channels and previously filled filled with epoxy resin-based cement. These teeth were retracted using different protocols and after analysis of the remnant volume they conclude that the use of the Clearsonic insert followed by Reciproc R25/.08 was the most efficient protocol for channel cleaning throughout its length (Rivera-Peña et al., 2018).

In 2021, Silva *et. Al*. also conducted a study involving the same ultrasonic insert, this time comparing it with the XP-endo Finisher R. The cement used was HA plus and the volume of remaining material quantified at from micro-computed tomography. Both methods complement each other were effective in reducing the amount of waste filled material, however, the XP-endo Finisher R has demonstrated higher efficiency than the ultrasonic insert (Silva et al., 2021).

PUI was originally conceived as a means of activating the irrigator without necessitating additional instruments for cleaning or disinfection, in this technique, an ultrasonic insert with reduced diameter and taper in relation to the channel, acts inside the main canal already prepared, thus avoiding contact with the dentin walls. Under these conditions, an acoustic flux is created with forces that cause the physical rupture of bacterial aggregations, such as biofilm. This technique has also been proposed to maximize removing material during retreatment. In this sense, the findings in the literature on that efficacy are divergent (Martins et al., 2017; Silveira et al., 2018; Kaloustian et al., 2019).

The study of Peña-Bengoa et al (2023) evaluate the effectiveness of ultrasonic activation in the penetration of intracanal medication. They notice that the utilization of ultrasonic technology increased the volume of medication that can be inserted into the canal, but they don’t find a difference in the amount of medication that is inserted into the canal with or without ultrasonic activation.

Also Kaloustian et al (2022) evaluate the ultrasound as additional activation and verify that the technique of retreating using sonic stimulation had a lower statistical probability of leaving behind residual filling materials.

Yang et al (2021) and Matoso et al (2021), conversely, found in their studies that although passive ultrasonic irrigation allows the remotion of remaining filling material, XP Endo Finisher efficiency was approximately doubled in curved canals and the PIPS are better in improving the removal of residual guta-percha.

For example, in the study of Yang *et al* (2021), when PUI and PIPS were incorporated into the mechanical removal of the remaining gutta percha and iRoot SP sealer, it was demonstrated that none of the additional methods completely eliminated the remaining iRoot SP and gutta percha. PIPS could remove more of the remaining filler material than CSI and PUI in the central portion of the cornea. In the middle and apical thirds, PIPS also had a greater degree of success in removing the majority of the remaining filling material than CSI, however, the difference among the PIPS and PUI groups was not symbolic. More material was excised in the PUI group than the CSI group in the top third of the apical direction. In regard to the different parts of the RC that were irrigated by the same final technique, PIPS and CSI had an equal amount of material removed from the remaining space in the RC. PUI had a greater effect on the middle and apical thirds of the spectrum, than on the coronal third.

They find that none of the additional methods successfully removed the remaining material. Compared to PUI and CSI, the activation of 2.5% sodium hypochlorite and 17% EDTA with PIPS increased the effectiveness of the procedure for removing the remaining material following the mechanical repairs of NiTi. (Yang *et al.,* 2021).

Similarly to that results, other previous investigations have demonstrated that PIPS employed after the NiTi instruments for repairs have a capacity to enhance the elimitation of the AH plus sealer (Keles *et al.,* 2016; Jiang *et al.,* 2016).

More recently, Petričević et al (2022) contrast the effectiveness of two different methods of activated irrigation, the Er:YAG laser and the ultrasonic technique of irrigation (UAI), as well as a conventional method of needling and cleaning, in the elimination of the bioceramic sealer during the conventional procedure of restaging in the RC and they conclude that all of the tested methods had a similar capacity to eliminate the remaining filling material.

Also, Küçükekenci and Küçükekenci (2019) assess the effectiveness of different methods of activating irrigation on the bond strength of fiber posts and the results showed that the examined methods had a small effect on the bond strength of fiber posts, but this was not found to be significant. They assess the effectiveness of methods for activating irrigation in increasing the bond strength of the fiber post to the dentin luted with self-adhesive resin cement (SARC), they also find that the apical regions have a substantially lower bond strength than the middle and coronal regions.

The third topic of this systematic review concerned efficacy of retreatment with ultrasound. The results of the various studies show that its impossible remove all the filled material of RC but the PUI can reduce the quantity of remanant filling material. It is also found in various studies that ultrasonic activation is less successful in the apical region, as it requires the oscillation of the instrument tip. When PUI is used in curved root canals, there may be contact of the file or ultrasonic tip with the dentin wall, which decreases its energy, and there may also be unintentional removal of the dentin (Eneide et al., 2019).

The process of removing the filler is a component of significant importance, as it facilitates the access of the instruments and solutions for irrigation to the necrotic tissues and remaining microorganisms, previously covered by the cement, thus promoting a better cleaning and therefore a more favorable prognosis.

With these results we demonstrated that ultrasonic use in endodontic retreatment is principally as a supplementary method for removing the filler.

3. CONCLUSION

Regarding the efficiency of ultrasonic passive irrigation in removing the filler material from RC, the results of this systematic review showed that isn’t capable of eradicating all traces of gutta-percha and filling cement from the roots of the canal, especially when the canal is flatted or has a isthmus.

Overall, the use of ultrasound as a secondary protocol in the endodontic retreatment demonstrated efficacy in removing the remaining filler material from the RC walls.

However, it is verified that the various studies present different protocols and are therefore heterogeneous and therefore it is impossible to indicate the best technique for removing the material that was filled.

Therefore, it is concluded that more studies using similar protocols are needed to obtain comparable results.

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