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State of the Art and Science in Endodontics: Literature Review

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Abstract

Objectives: To review the current methods and techniques used in endodontics, including both mainstream and less widely used approaches. To describe the current status of artificial intelligence and its future directions. To discuss tissue engineering. **Materials and Methods:** Our literature search was conducted using PubMed, ScienceDirect, Scinapse, and Cochrane as databases. The selection was based on recent studies from the past 10 years. Eligible articles included those relevant to the research question, those written in French or English, those based on scientific evidence, those with no conflict of interest, and those adhering to ethical standards. **Results:** This study highlights the necessity and limitations of technologies as aids in the management of endodontically treated teeth. New diagnostic tools such as pulse oximetry, laser Doppler flowmetry, dual-wavelength spectrophotometry, and the Diagnodent laser system offer reliable methods that surpass conventional sensitivity tests. Other advances include magnification, the design of access cavities that promote the preservation of dental tissue, as well as new methods of chemomechanical preparation and shaping. Finally, root canal obturation benefits from new materials such as bioceramics. **Conclusion:** Several diagnostic tests, access cavity design methods, and file and root canal sealing systems are available to help clinicians provide the best treatments. The practitioner must choose those that best suit the clinical case, their preferences, and, above all, their level of expertise. A comprehensive overview and careful case selection are essential for achieving a favorable outcome. In some cases, it is necessary to consider contemporary endodontic procedures for pulp preservation or regeneration.

Subject Areas

Dentistry

Keywords

Artificial Intelligence, Gutta-Percha, Filling, Irrigation, Diagnosis, Pulpal Vitality, Tissue Engineering, Revascularization, Endodontic Guide, Access Cavity, Imaging.

1. Introduction

The diagnosis of the condition of the dental pulp should be viewed as a synthesis of the medical history, clinical examination, specific tests, and radiographic examination, rather than as the result of a single test. The ideal method for pulp testing must be objective, reproducible, painless, and accurate. This paper reviews the advances of the past decades to help the practitioner diagnose and treat endodontic conditions in a contemporary manner, addressing all stages of management, from diagnosis to root canal obturation, while explaining the necessity and limitations of technologies as aids in the management of affected teeth [1].

2. Methodology

In order to address the research question focused on "How can endodontic treatment be successfully performed using the most recent tools, instruments, techniques, and materials in dentistry?", we conducted an exhaustive literature review, drawing on articles published in literature. To this end, the scientific search engines we used were the following: PubMed, ScienceDirect, Scinapse, and Cochrane. For these sources, a time frame was predefined using the available filters. The inclusion criteria were therefore: a publication date between 2012 and 2022; articles that align with the research question; articles written in French or English and articles that comply with ethical standards. The exclusion criteria, meanwhile, are as follows: articles published before 2012; articles whose subject matter does not focus on technologies or materials that have recently emerged for the purpose of performing endodontic treatment on a tooth using the most up-to-date methods; articles published in a language other than French or English; and articles that are not based on scientific evidence and lack ethical merit. Thus, the search strategy was based on a strategic selection of keywords or MeSH terms. During the literature review, an initial selection of articles was based on titles and abstracts; a second selection of articles was made after critical reading; and finally, we proceeded to synthesize the collected data. The MeSH terms used were as follows: Recent systems and endodontics, Advanced techniques and endodontics, Evolution of instruments and endodontics. The Boolean operator "and" was incorporated into the search query to identify terms common to the targeted sets. At the conclusion of the search and after eliminating duplicates, a total of 1340 articles were identified. After reviewing the titles and abstracts, a total of 763 articles were retained for selection. Finally, following a full-text review, we retained 42 articles and one scientific book in digital format (**Figure 1**). A critical and targeted review of the data collected on the research topic followed in order to best answer the research question.

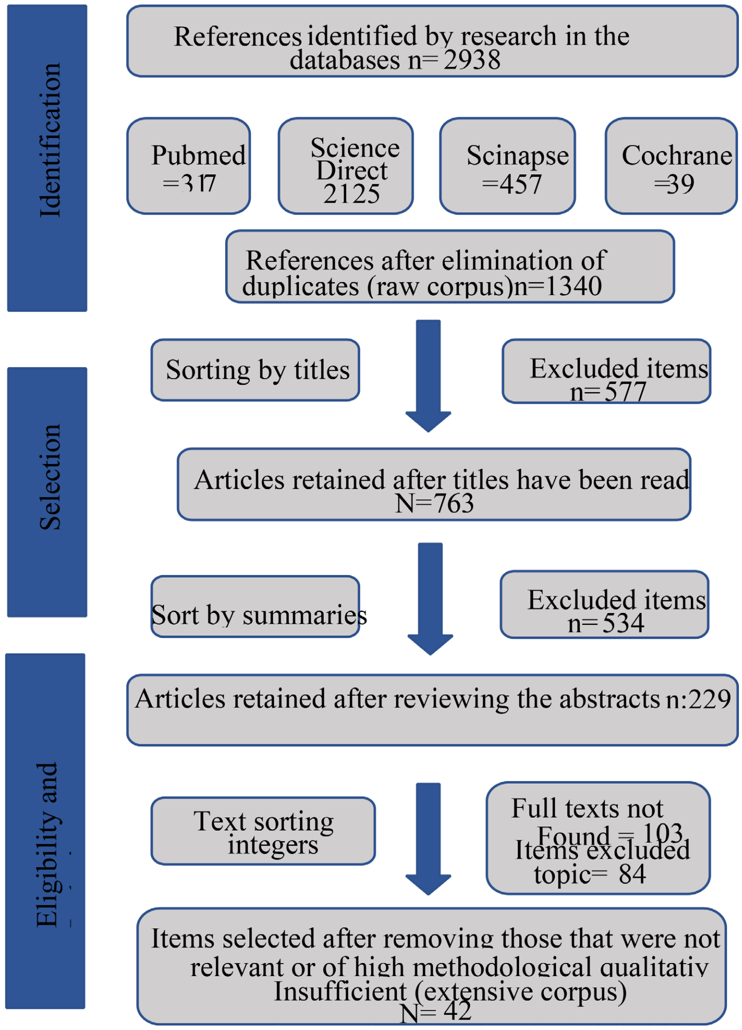

Figure 1. Summary diagram of the steps taken and the number of articles used at each stage of sorting the raw corpus.

3. Results

3.1. Diagnosis in Endodontics

Diagnosis involves collection of information by history taking and clinical examination of patient which is confirmed by using various diagnostic aids and more precise and elaborated information is obtained from these diagnostic aids [1].

3.1.1. Current State of the Art and Technological Advances

Recent diagnostic technologies help in detection of dental problems at their early stages, which helps in providing non-invasive intervention as early as possible to prevent further damage [1].

Pulse oximetry

Rapid advances in knowledge and applied technologies related to pulp blood flow could pave the way for more objective, accurate, and predictable methods of assessing pulp vitality [2].

Pulse oximetry is a non-invasive diagnostic tool used to monitor oxygen saturation (SpO2), originally developed for general medical use. In endodontics, this technology is applied to assess pulp vitality by focusing on vascularization rather than innervation. The principle relies on the differential absorbance of red and infrared light between oxygenated and deoxygenated hemoglobin. This approach enables the detection of active blood flow even when nerve fibers are temporarily non-responsive, a common occurrence following dental trauma [3]. **Table 1** summarizes the main advantages and disadvantages of pulse oximetry in endodontics.

Advantages and Disadvantages [2]

Table 1. Overview of the advantages and disadvantages of pulse oximetry in endodontics [2].

Advantages	Disadvantages
• An objective and effective method for assessing pulp vitality. • Useful in trauma cases where blood supply remains intact but innervation is damaged. • Pulp pulse readings are reproducible.	• Background absorption related to venous and tissue blood components is not differentiated. • The probe must be adapted to dental anatomy, as oxygen saturation in teeth is lower than in the finger.

Laser Doppler flowmeter

Laser Doppler flowmetry is a non-invasive electro-optical technique providing semi-quantitative measurement of pulp blood flow, even within the microcirculation [2]. The principle relies on the frequency shift (Doppler effect) of light scattered by moving red blood cells, unlike static tissue. Signal accuracy depends on proper calibration and the elimination of contamination from non-pulp blood flow [1].

1) Indications [2]

In cases of periapical radiolucencies of non-endodontic origin, vitality tests such as LDF allow for differential diagnosis between endodontic and periodontal lesions. LDF is also effective for monitoring the revascularization of reimplanted teeth, distinguishing a vital tooth from a necrotic tooth. **Table 2** summarizes the main advantages and disadvantages of the laser Doppler flowmeter in endodontics.

2) Advantages and Disadvantages [2]

Table 2. Advantages and disadvantages of the laser Doppler flowmeter in endodontics [2].

Advantages	Disadvantages
• Accurate • Non-invasive • Effective in children whose responses are unreliable.	• High cost • The light beam must interact with mobile cells circulating in the pulp vascular system. • Bias: interference with supporting tissues can lead to false-positive results.

Dual-wavelength spectrophotometry

Dual-wavelength spectrophotometry is a method for measuring oxygenation and blood volume that does not depend on pulsatile circulation [2]. By utilizing two specific wavelengths (760 and 850 nm), it directly detects pulp oxygenation and transmits data to a continuous recorder that converts it into information on vascular status [2].

Advantages [2]

- Affordable price
- Portable and easy to use
- Uses filtered visible light guided to the tooth via optical fibers.
- Objective results

Diagnodent Laser System

This technology utilizes laser fluorescence to detect structural changes in teeth caused by demineralization [1]. The Diagnodent employs a 655-nm laser diode transmitted via optical fiber, allowing for the real-time detection of demineralization and bacterial products. While it can identify very low levels of bacterial metabolites, its results can be hindered by the presence of plaque, filling materials, or prophylactic sealants [1].

3.1.2. Recent Advances in Magnification in Endodontics

Due to the nature of their specialty, endodontists must have a firm grasp of the art of diagnosis. To this end, the use of magnification would be a valuable asset in many clinical situations [4].

Rod-lens endoscope

The use of a cylindrical-lens endoscope serves as a useful magnification tool for conventional surgical endodontics. A cylindrical-lens endoscope (**Figure 2**) consists of glass rods, a camera, a light source, and a monitor. A digital recorder for continuous video or still image capture can be added to the system to ensure traceability and documentation of the procedure [5].

Figure 2. Rod-lens endoscope (JEDMED, St. Louis, MO.

Orascope

The orascope is a lightweight, flexible fiber-optic endoscope featuring a 0.8-mm tip and approximately 10,000 imaging fibers, surrounded by light-emitting fibers for intracanal visualization. (**Figure 3**) [6].

Surgical microscope

Today, advancements in visualization in dentistry have shifted from the use of loupes and headlamps to the use of optical microscopes. The magnification

Figure 3. An orascope.

required for root canal treatment is generally 3× to 30× [6].

In the literature, the use of the microscope in endodontics offers several clinical advantages: better visualization of the treatment area and root canal orifices, assistance in removing fractured instruments, detection of microfractures, assistance in treating perforations, as well as the ability to document cases [6].

Keplerian loupe

Keplerian loupes are the most optically advanced loupes. They offer up to 6x magnification and surpass other loupes in terms of field of view, depth of field, and working distance, with the potential to replace microscopes in root canal treatment [7].

3.1.3. Recent Advances in Radiography in Endodontics

Specialized radiographic technique is used for specific diagnostic task. Some of the techniques have been available to diagnose at years, others are more recent. Advance imaging techniques have advantages like reduced exposure 3D reconstruction with the help of computers, easy to store patient data [8].

Cone Beam Computed Tomography

Recently, a new generation of more practical tomography has emerged: cone-beam computed tomography (CBCT). CBCT is a 3D radiographic tool that allows for an understanding of the spatial relationships of the maxillofacial complex and anatomical structures. CBCT has the potential to become a routine non-invasive diagnostic tool for a variety of dental applications [8]. **Table 3** summarizes the main advantages and disadvantages of cone-beam computed tomography in endodontics.

1) Uses [8]

- Assessment of root canal morphology
- Diagnosis of endodontic pathologies
- Evaluation of non-endodontic pathologies
- Evaluation of root fractures
- Analysis of internal and external root resorption
- Identification of untreated or unmarked canals

2) Advantages and Disadvantages [8] [9]

Table 3. Advantages and disadvantages of the cone beam computed tomography [8] [9].

Advantages	Disadvantages
• High accuracy • Reduced scan time and thus radiation dose (CBCT with small FOV) • Elimination of overlap from surrounding structures	• Limited availability • Significant capital investment • Requires in-depth knowledge of radiological and anatomical interpretation

3.1.4. Molecular Diagnostics in Endodontics

Molecular diagnostics make it possible to determine the spatial extent of tissues infected or damaged by infection and, thereby, the extent of the surgical intervention and debridement required in certain clinical situations. In restorative dentistry and endodontics, it allows for an assessment of the overall condition of the pulp [10].

How can molecular diagnostics be useful?

Subjective pulp sensitivity tests must be replaced by precise and specific methods. Molecular diagnostics allows for the localization of infected tissues and the assessment of pulp condition, providing diagnostic and decision-making value for treatment [10].

Example of periapical fluid

Periapical fluid, present around the dental apex, becomes an exudate in cases of inflammation, with its composition varying depending on the severity. Collected during endodontic treatment, it contains factors correlated with clinical symptoms and the size of radiographic lesions, which decrease after treatment. Its analysis can serve as a molecular marker to monitor healing, as changes appear rapidly, allowing an assessment as early as the second session of whether obturation is possible or if additional disinfection is necessary [11].

3.2. New Concepts in Modern Access Cavities and Technical Advances

Endodontic access cavities were designed according to standardized shapes to ensure visibility and access to the canals, but without preserving the tissues. Over the past decade, minimally invasive dentistry has prioritized maximum protection of dental tissues [12].

3.2.1. Conventional Endodontic Access Cavity

The traditional access cavity (TAC), derived from Black's preparations, involves removing the caries and then the roof of the pulp chamber to expose the canals and gain access to the apical foramen after enlargement. It is intended for the localization, chemomechanical preparation, and obturation of the canals; however, some authors believe that it removes too much dentin and weakens the tooth, leading to the development of new models [13].

3.2.2. Recent Design of the Endodontic Access Cavity

The past decade has seen significant developments in "minimal interventions," which have critically reevaluated many traditional principles taught in the past. "Minimally invasive dentistry" is the latest approach aimed at maximizing the preservation of dental tissue. This conservative approach has spurred technological advances [14].

Conservative endodontic access cavity

The conservative access cavity, proposed by Clark and Khademi, reduces loss of tooth structure and preserves mechanical stability. Access is gained through the central fossa, which is enlarged to expose the canals while protecting the pericervical dentin and part of the pulp floor, thereby maintaining the biomechanical response of the root dentin [15].

Ultra-conservative access cavity/"Ninja" endodontic access cavity

Ultra-conservative access cavities, known as "Ninja" (CAN), are derived from CACs but with reduced extensions, preserving the roof of the pulp chamber as much as possible. They nevertheless allow for the localization and access to all canals [16].

Orifice-oriented access cavity for dentin preservation/Truss access cavity

The "Truss" access cavity (TEAC) (**Figure 4**) [14] is a conservative approach in which separate cavities provide access to the canals while leaving a "truss" of dentin. It preserves dental tissues but is limited by the tooth's position, the mouth opening, and calcification, requiring extensive training and technical skills [15].

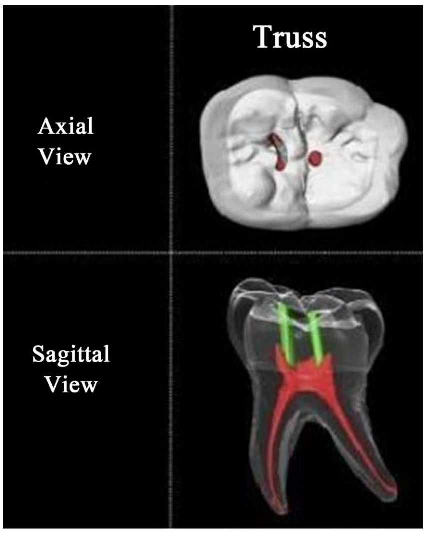

Figure 4. Microtomography illustration of a mandibular first molar showing ultra-conservative access cavity preparations. The access is shown in s from the occlusal and vestibular views. The green area represents the tooth structure removed during access preparation.

Computer-Assisted Access Cavity

Computer-aided access cavities (CAACs) use software and 3D imaging to plot a predictable path to the root canal space, preserving tooth structure. Inspired by implantology, this method constitutes a minimally invasive approach. CAACs can be classified into two types [15]:

The guided access cavity

The guided access cavity (GAC), based on CBCT and a custom guide, allows for conservative, operator-independent access. Its limitations include planning time, treatment delay, the mandatory straight trajectory, difficulty accessing posterior teeth, overheating, and reduced precision due to artifacts [15].

The dynamically navigated access cavity

Dynamic navigation in endodontics using the DENACAM system employs miniaturized cameras and markers to guide the axis and depth of the preparation in real time. It offers precision comparable to static navigation, with no notable difference in cavity deviation. Advantageous for patients with limited mouth opening, it avoids the constraints of guides [16].

3.3. Technical and Technological Advances in Chemo-Mechanical Shaping in Endodontics

Root canal preparation removes tissue, necrosis, and biofilms, while shaping the canal to facilitate irrigation and obturation. Sodium hypochlorite is the most commonly used antimicrobial agent, but its effectiveness is limited in complex areas. Irrigation dynamics are essential for optimizing disinfection, as syringe irrigation remains passive and ineffective [17].

3.3.1. Evolution of Rotary Instrumentation in Endodontics According to Leonardo MR and De Toledo Leonardo R

Mechanized NiTi alloy instruments possess superelasticity and shape memory properties, offering superior flexibility and strength [18].

First-generation rotary systems (NiTi)

This generation of files is widely used in endodontics [18]:

- Quantec System (Tycon/Analytic Endod/Kerr-USA).
- ProFile System 04/.06 (Dentsply/Maillefer-Switzerland).
- K3 Endo System (SDS Kerr-Sybron Endo-United States)
- Mtwo® System (VDW Dental-Industrie).
- ProTaper® Original (Dentsply/Maillefer-Switzerland).
- ProTaper Universal (Dentsply/Maillefer-Switzerland).

NiTi systems offer flexibility, cutting efficiency, and time savings, but present a risk of fracture, insufficient cleaning in flattened canals, and high costs due to their limited use [18].

Second-generation rotary systems (NiTi Phase R)

NiTi Phase R alloy instruments, developed through heat and torsion treatments, improve flexibility and reduce the risk of fracture. The intermediate phase (R) allows the instrument to be twisted while cutting dentin without microfractures, thereby increasing its strength and flexibility. These new-generation files are among the most widely used systems [18]:

- K3 XF (Sybron EndoKavo/Kerr) Phase R/Wear.
- Twisted file (Phase R-Twisted).
- Easy Shaper (Phase R-Easy Dental Equipment-Belo).

- Horizonte, MG, Brazil.

1) Advantages [18]:

- High resistance to cyclic fatigue and torsion.
- Lower fracture index.
- Improved cutting efficiency.
- Shorter working time, reducing stress for the professional.

2) Disadvantages [18]:

- High cost because they can only be used once.
- Risk of fracture is still present, but with a lower incidence than with first-generation instruments.

Third-generation rotary systems: (NiTi, M-Wire)

Instruments manufactured with this alloy are [18]:

- ProFile® GT (Great Tapers).
- Series X (NiTi M-Wire) (Dentsply/Maillefer-Switzerland).
- ProFile® Vortex™ (NiTi M-Wire) (Dentsply Tulsa/Dental-United States).
- Protaper Next (NiTi M-Wire) (Dentsply Tulsa/Dental-USA).

NiTi M-Wire instruments, which are more flexible due to a lower modulus of elasticity, improve the microstructure of NiTi. They enable the manufacture of instruments such as the ProGlider™ for the glide path, as well as reciprocating systems such as Wave One™ and Reciproc™, which are widely used in endodontics [19]:

1) Advantages [18]:

- High resistance to cyclic fatigue and torsion.
- Lower fracture rate with repeated use.
- Greater cutting efficiency.
- Greater flexibility compared to the first generation (15% more flexible).

2) Disadvantages [18]:

- Higher cost: according to the manufacturer, they should only be used once.
- Risk of fracture, though with a lower incidence compared to instruments of the previous generation.

Fourth-generation rotary systems (CM NiTi)

Fourth-generation systems use controlled-memory NiTi CM alloys. HyFlex™ EDM files, manufactured by electrical discharge machining, have a rough surface that increases their lifespan and resistance to cyclic fatigue, up to 700% greater than HyFlex® CM™, making them suitable for highly curved canals [18].

Instruments manufactured using this technology include [18]:

- NiTi CM-495 alloy: Coltene Hyflex system (United States), Easy Pro Design system (Brazil).
- NiTi CM-495 EDM alloy: HyFlex® EDM system.
- NiTi CM-500 alloy: XP-Endo (FKG Dentaire-Switzerland).

1) Advantages [18]:

- Root canals with high anatomical complexity.
- High resistance to cyclic fatigue.

- Lower fracture index: 300% stronger.
- Greater cutting efficiency.
- Greater flexibility: 80% more flexible than conventional instruments.

2) Disadvantage [18]:

- Less suitable for wide or relatively wide and straight canals.

Fifth-generation rotary systems (NiTi, Gold)

This is a method for manufacturing nickel-titanium alloy files with GOLD treatment, one of the commercial forms of which is the Pro Taper GOLD™ (Dentsply/Sirona-United States) [18].

1) Advantages [18]:

- 80% more flexible than files from conventional rotary systems.
- 150% more resistant to cyclic fatigue compared to the Universal Pro Taper system.
- Shorter treatment time.

The Wave One® Gold retains the advantages of the Wave One®, while offering 50% additional resistance to cyclic fatigue and 80% more flexibility, thanks to the heat treatment of NiTi combined with reciprocating motion, which improves its performance in endodontics [18].

Next-generation systems

Instruments manufactured with this alloy are:

NiTi Blue

NiTi Vortex Blue™ instruments, made of Nitinol 508 alloy and coated with a layer of blue titanium oxide, differ from traditional super-elastic NiTi instruments. Thanks to specific thermal processes and shape memory, they offer high flexibility [18].

1) Advantages [18]:

- Root canals with significant anatomical complexity.
- High flexibility: follow the natural curvature of the root canal.
- Greater resistance to cyclic fatigue.
- Reduced memory effect of the instrument, resulting in less resistance when the instrument is inserted into the root canal.

Reciprocating systems

Reciproc® Blue files differ from conventional Reciproc® files due to an improved NiTi alloy. Thermomechanical treatment modifies their molecular structure, giving them increased resistance to cyclic fatigue, superior flexibility, better memory control, and a characteristic blue color [18].

1) Advantages: Reciproc® Blue offers high flexibility, allowing for gentler and safer penetration into the root canal, with better centering and increased resistance to cyclic fatigue [18].

3.3.2. The Influence of the Different Phases of the Niti System on Their Behavior

NiTi is a highly flexible alloy five times more flexible than stainless steel and 10 times more resistant to stress. Super-elastic, with shape memory, biocompatible, and corrosion-resistant, it does not weaken after sterilization despite its complex manufacturing process. It exists in two crystalline phases: austenite at rest and martensite under stress, the latter being a hard metastable structure. (**Figure 5**) [19].

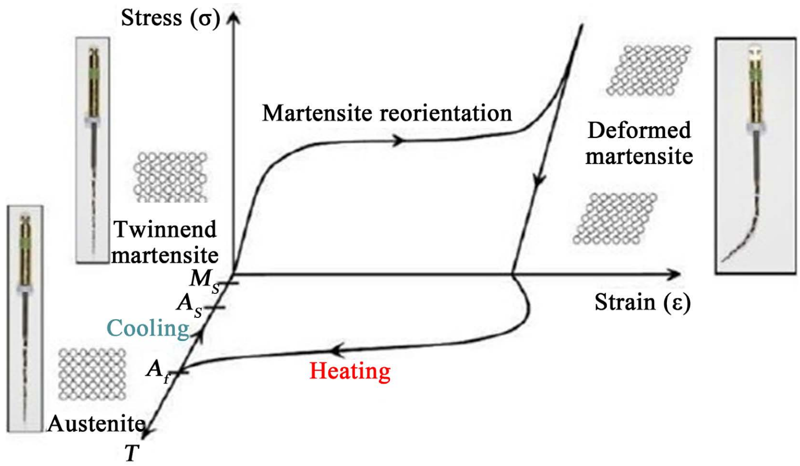

Figure 5. Stress-strain-temperature diagram showing the shape memory effect of martensitic NiTi instruments. The stress plateau is due to the reorientation of the martensite.

3.3.3. Irrigation Activation Systems

Traditional irrigation activation systems

The mechanical activation technique involves manually agitating the irrigant, for example with an endodontic file actively moved within the canal. It promotes penetration and reduces air bubbles, but does not improve final cleaning [20].

New types of irrigation activation systems

Advances in manual systems have led to the introduction of instruments that can be rotated by low-speed handpieces inside the canal filled with irrigant [21].

Assisted agitation systems

The rotary handpiece with a microbrush, invented by Cliff Ruddle, removes debris and dentin sludge from instrumented canals by rotating at 300 rpm, serving for debridement or agitation of the irrigant. More recently, the NaviTip FX irrigation needle, a 30-gauge needle covered with a brush, has been introduced to the market [21].

Continuous irrigation during instrumentation

The Quantec-E irrigation system is a self-contained unit that, during rotary instrumentation, continuously agitates the irrigant, increasing its volume, contact time, and penetration into the canal. Studies show that it improves the removal of debris and dentin sludge, especially in the coronal third of the canal walls [21].

Sonic Activation

The Vibringe® system (**Figure 6**) is a sonic device that combines the delivery and activation of the irrigation solution in a single step. Acoustic activation promotes the breakdown of dentin sludge and biofilm, improving treatment success. It consists of a refillable syringe and a needle that activates the irrigant sonically

[21].

EndoActivator

The EndoActivator®, is a sonic irrigation system consisting of a portable handpiece and three disposable polymer tips of different sizes. It effectively cleans debris from lateral canals and dislodges dentin sludge and biofilm, particularly in the curved canals of molars [21].

Ultrasonic Activation

Ultrasonic energy (25 - 30 kHz) has lower amplitudes but higher frequencies than sonic energy (**Figure 6**). It is recommended as a supplement after canal preparation, not as an alternative to conventional instrumentation. This system improves cleanliness through the vibrational movement and the effectiveness of the ultrasonic file within the canal space [21].

Figure 6. Ultrasonic irrigation system.

Negative-pressure apical irrigation

They are categorized by:

The RinsEndo system

The RinsEndo system (**Figure 7**) uses pressure-driven suction technology, in which 65 ml of solution oscillating at 1.6 Hz is delivered to the canal via a cannula. During suction, air and the used solution are mixed with fresh solution. According to the manufacturer, the pulsating flow allows for effective rinsing of the apical third, although the cannula remains limited to the coronal third [21].

Figure 7. RinsEndo system.

The EndoVac Pure System

The EndoVac Pure system uses cartridges with Macro Pure and Micro Pure cannulas for ease of use. It facilitates the delivery and propagation of endodontic irrigation solutions, as well as the removal of damaged or necrotic pulp debris, while reducing the risk of irrigation-related accidents [21].

Laser Activation

Laser-activated irrigation (LAI) and PIPS technology rely on the interaction between the laser and the irrigant.

(Figure 8) [21]. The absorption of laser light by sodium hypochlorite causes vaporization and the formation of vapor bubbles, whose implosion generates secondary cavitation effects. With the Er:YAG laser, the PIPS technique produces photoacoustic shock waves in the irrigant, inducing a photomechanical phenomenon [21].

Figure 8. Laser irrigation.

3.4. Root Canal Filling in Endodontics: Latest Scientific Advances

Root canal obturation aims to ensure a hermetic seal against microorganisms while preserving the tissues. It must also be simple to perform, controllable, and retrievable in case of failure. However, these requirements are not always met by current materials, whose main limitation remains the difficulty in achieving a perfectly hermetic seal [17].

3.4.1. Recent Advances in Root Canal Filling Materials

Recent advances in root canal treatment include:

Epiphany/Resilon®

Resilon® is a heat-activated resin in cones, used with **Epiphany** cement to adhere to dentin and ensure a good seal. Biocompatible like gutta-percha, it has lower bond strength but superior sealing ability. Further clinical studies are needed to confirm its efficacy [22].

EndoREZ

This is a self-adhesive, UDMA-based, hydrophilic, two-component, dual-curing endodontic cement. Its hydrophilic nature allows it to penetrate the dentinal tubules without compromising adhesion or polymerization. It is intended for use with EndoREZ tips or gutta-percha for root canal obturation [23] [24].

Activ GP

The Activ GP system uses laser-calibrated gutta-percha cones compatible with files having a taper of 0.04 or 0.06. The glass ionomer cement bonds directly to the dentin. The chemical and micromechanical adhesion between the walls, cement, and cones creates a monolithic structure that ensures a hermetic seal from the orifice to the apex [25].

Smartseal

The Smartseal system uses hydrophilic cones that absorb moisture and expand to fill voids. They feature a flexible core and an outer hydrogel layer that allows for expansion within the root canal branches. Its advantages include geometric precision, controlled expansion, and biocompatibility [26].

Realseal

RealSeal is a synthetic polyester filling material with bioactive and radiopaque fillers, offering strength and reduced microleakage [24]. Its dual-curing cement contains calcium hydroxide, sulfate, barium glass, and silica. Together, these form a single unit connecting the wall, cement, and cones, ensuring increased root sealing and strength [21].

3.4.2. Bioceramic-Based Root Canal Cements

Bioceramics include alumina and zirconia, bioactive glass, coatings and composites, hydroxyapatite, and resorbable calcium phosphates [27].

Bioceramics are classified as follows [27]:

- Bio-inert: Do not interact with biological systems
- Bioactive: Durable in tissues and capable of interfacial interactions with surrounding tissues
- Biodegradable, soluble, or resorbable: Eventually replaced or incorporated into newly formed tissues.

Specific Properties and Composition

BioRoot™ RCS is a tricalcium silicate-based, bioactive, and biocompatible endodontic sealer composed of zirconium oxide, a hydrophilic polymer, water, and calcium chloride. It promotes periapical healing through its alkaline pH, sealing properties, and stimulation of dentin mineralization. Indicated for permanent fillings with gutta-percha cones, it is used as a single cone, with cold lateral condensation, or with hot gutta-percha filling [28].

BioRoot™ RCS ensures a tight seal between dentin and gutta-percha, with adequate radiopacity. Its fluid, homogeneous paste adheres to instruments for optimal placement. Thanks to monomer-free Active BioSilicate technology, it does not shrink during setting, guaranteeing a tight root canal seal [28].

Description of the Surgical Technique

The operative sequence is as follows [28]:

Conical shaping of the canal, disinfection with sodium hypochlorite and EDTA, followed by drying with paper points. Preparation of BioRoot™ RCS cement, insertion of the gutta-percha cone, and advancement to the determined length. Resection of the cone at the canal entrance using a heated probe, followed by light manual condensation.

4. Discussion

4.1. A New Era That Overlaps with Old Practices

Diagnosis is the art of identifying the problem and using scientific knowledge to determine its cause.

The goal of diagnosis in endodontics is to assess the condition of a tooth and identify the cause of discomfort. Over the years, thermal and electrical tests have become very common for assessing tooth vitality [29].

4.1.1. Comparison of New Diagnostic Methods and Traditional

Several studies have compared new methods of pulp evaluation with conventional tests. Janani K. *et al.* (2020) demonstrated 100% accuracy for the oximeter, compared to 66% for cold, 49% for thermal, and 45% for electrical testing. Despite this, the oximeter remains rarely used in clinical practice [30].

A systematic review published in 2018 by Gouth *et al.* aimed to evaluate the evidence from clinical studies on the use of the LDF in assessing and monitoring the pulpal condition of permanent teeth compared to other sensitivity and/or vitality tests. The results unanimously agreed that the use of the LDF was more reliable than routine sensitivity tests. The LDF showed a sensitivity of 81.8% to 100% and a specificity of 100% in three studies. Similarly, the LDF was compared to the electrical pulp test (EPT) in three studies, where the EPT showed a sensitivity and specificity of 63.3% to 91.5% and the LDF of 88% to 100%. LDF was compared to ethyl chloride in only one of the included studies, showing a sensitivity of 92% and a specificity of 89%. The accuracy and reproducibility of LDF compared to four other pulp tests were reported in the fourth study, with a score of 96.3% versus 65% for the other tests [31].

4.1.2. Comparison between Resilon and Gutta-Percha

A clinical study by Pandey P *et al.*, published in 2020, shows a higher rate of degradation of Resilon compared to gutta-percha over a relatively long period of time, which could be attributed to complications with intracanalar adhesion caused by the polymerization shrinkage of Resilon. on the other hand, P Pandey *et al.*, in 2020, conducted a systematic review and meta-analysis of the effect of dentin slurry on the sealing ability of the filling, It was concluded that removing the dentin slurry layer improves the sealing ability of the filling system, whereas other factors such as the filling technique have no significant effect, concluded that the removal of dentin slurry improves sealability, whereas the filling technique has no significant effect [32].

4.1.3. Comparison of CBCT, Panoramic Radiography, and Retroalveolar Radiography in Assessing the Healing Process of Periapical Periodontitis

Radiography is essential for endodontic diagnosis and follow-up. The systematic review conducted by Antony D. P. *et al.* (2020) compared periapical and panoramic radiographs with CBCT to detect periapical lesions after treatment. One included study (36 patients, 46 teeth) showed that CBCT detected more lesions than periapical radiography and provided additional clinical information, particularly regarding root anatomy and surrounding structures.

Conclusion: CBCT is the most accurate method, followed by periapical radiography, then panoramic radiography [33].

In endodontics, imaging is essential for diagnosing periapical lesions, yet conventional radiography and CBCT show limited reliability (26% - 54.3% and 61% - 76%, respectively) in differentiating cystic from non-cystic lesions.

Ultrasonography (USG), based on ultrasonic wave reflection at tissue interfaces, demonstrates markedly higher accuracy (86% - 100%). Distinct echographic patterns allow differential diagnosis: **cystic lesions** appear as well-defined hypoechoic cavities without vascularization; **granulomas** as poorly defined hypo-echoic areas with rich vascular supply; and **mixed lesions** as predominantly hypoechoic zones with focal anechoic regions and localized vascularity. These findings position USG as a more reliable and promising modality than conventional radiography and CBCT for the evaluation of apical lesions [34].

Furthermore, disinfection of the root canal system remains a critical challenge in endodontic therapy. Innovative strategies including photoactivated disinfection, the GentleWave® system, ozone application, nanoparticles, and non-instrumentation techniques have been introduced to enhance biofilm eradication in anatomically complex areas that are otherwise difficult to access. Several investigations have reported encouraging outcomes, particularly with the GentleWave® system [35].

4.2. Artificial Intelligence in Endodontics

In healthcare and medical professions, AI is a general term used to describe the use of algorithms and machine learning software that mimic human cognition in the analysis, presentation, and understanding of medical data. According to the "National Strategy on Artificial Intelligence" published in 2018 by Niti Aayog, healthcare remains the top priority for AI development [36].

4.2.1. Detection of Periapical Lesions

Research shows that artificial intelligence can match or outperform practitioners in detecting periapical lesions. Endres *et al.* demonstrated that a deep learning algorithm achieved the performance of 24 surgeons on panoramic radiographs. Other studies have confirmed that CNNs were more sensitive and specific than experienced radiologists or dentists. However, these studies remain limited by sample size and the use of panoramic radiography, which is uncommon in endodontics [36].

4.2.2. Detection of Root Fractures

Vertical root fractures (VRFs) account for 2% - 5% of dental fractures and are a serious complication that can lead to resection or extraction. Their diagnosis is difficult: CBCT is more effective for unfilled teeth, while radiographs are slightly more effective for filled teeth. Convolutional neural networks (CNNs) show potential on panoramic radiographs. It was concluded that the mean sensitivity and specificity values of the CNN group were superior to those of interpretations by oral and maxillofacial radiologists [36].

4.2.3. Determination of Working Length

Correct determination of the working length is essential for the success of root canal treatment. Methods include radiography, patient response, tactile detection, electronic apex locators, and CBCT. In practice, radiography and apex locators are the most commonly used. The quality of digital images strongly influences interpretation, but other factors can lead to errors. Hence, the need to develop computational methods for accurate and reproducible determination of the working length. These results confirm earlier findings by Khanagar *et al.* (2021) in a broader systematic review on AI in dentistry [36] [37].

4.3. Future Directions and Reliability of AI

Artificial intelligence has gained prominence as a central concept as we observe significant advancements in technology and science. Patient data assessments by dentists are subjective, and research findings have shown that diagnoses are not always consistent among practitioners. New smart dental technologies offer a way to significantly improve consistency and, consequently, patient health. Dental research should enhance the relationship between oral health and overall health in the future, focusing on individualized, patient-centered treatment. Robotic assistance in dentistry has become possible thanks to technological advancements [38].

New perspectives and reliability of AI according to Mohamed Isaqali Karobari *et al.*

AI systems can revolutionize medicine and dentistry by finding solutions to various clinical problems and facilitating the work of clinicians. When AI is combined with endodontics, root canals can be prepared biomechanically with precision. The latest advances in digital applications have also fostered the creation of clinical techniques such as AI-based diagnostics and assisted access cavity preparations for easy access to root canals, even in obliterated roots. This latter technique involves a new concept of guided endodontic access (GE), which is based on the use of protocols from guided implantology to achieve safe access to the cavity in challenging cases such as calcified pulp chambers. Multiple studies have also demonstrated the use of this new concept for the diagnosis of endodontic diseases and treatment planning. Using color photographic images of teeth [39].

4.4. Current Clinical Practice and Prospective Applications in Regenerative Endodontics

Recent advances in research, which demonstrate that the dentin-pulp complex is capable of self-repair and regenerating mineralized tissues, raising hopes for new treatment modalities capable of protecting the vital pulp, stimulating reactive dentinogenesis, and promoting the revascularization of a necrotic root canal system. The volume of an adult pulp is relatively small (less than 100 µl), so one might predict that the regeneration of this tissue would be relatively simple. At present, however, these approaches have not been translated into clinical practice, as significant obstacles remain [40].

4.4.1. Revascularization, Revitalization and Pulp Regeneration

Although current therapeutic approaches provide reliable results, a better approach for endodontic treatment in the future could be to stimulate the synthesis of new pulp or connective tissue within the canal system *in situ* [41].

Revitalization is a technique that aims to fill the pulp space with vital tissue. This replacement tissue is different from that which was originally present in the canal and will not transform into dentin. Regeneration implies that the pulp tissue reforms within a vacant canal space and can then perform a normal homeostatic function. If this definition is accepted, then none of our current therapeutic strategies can be considered regenerative, as none fulfills these conditions. Instead, current treatments should be considered purely restorative [41].

4.4.2. Revitalization Protocol (Recommendation of the European Society of Endodontology, ESE) [41].

➢ **Session number 1:**

• Clean the teeth, anesthetize, isolate, and disinfect the working area (e.g., with povidone-iodine). • Prepare the access cavity. • Remove loose or necrotic pulp tissue using appropriate endodontic instruments. • Avoid mechanically instrumenting the canal walls. • Irrigate with 1.5% - 3% sodium hypochlorite (20 mL, 5 min) using a side-vented needle positioned 2 mm above vital tissue. • Bleeding or exudate (check with paper points) may require prolonged irrigation. • Irrigate with 0.9% saline (5 mL) to minimize the cytotoxic effects of sodium hypochlorite on vital tissue. • Dry with paper points. • Irrigate with 20 ml of 17% EDTA. • If signs of inflammation have not resolved, replace the calcium hydroxide. Systemic administration of antibiotics may be considered at this stage.

➢ **Session number 2 (2 to 4 weeks later):**

• If signs of inflammation have not disappeared, replace the calcium hydroxide. Systemic administration of antibiotics may be considered at this stage. • Clean, anesthetize, isolate, and disinfect the work area. • Remove the material. • Irrigate with 17% EDTA (20 mL, 5 min), using a side-vented needle, placed 2 mm above vital tissue. • Irrigate with 0.9% saline (5 mL) to reduce adverse effects of the irrigants on target cells. • Dry with paper points. • Induce bleeding by mechanically irritating the periapical tissues and by the rotating motion of an apically precurved file. • Allow the canal to fill with blood to within 2 mm, below the gingival margin and wait for the blood clot to form for 15 minutes. • Cut a collagen matrix with a diameter larger than the coronal portion of the canal, place it over the blood clot, allow the matrix to become saturated with fluid, and prevent the formation of a hollow space. • Place the calcium-silicate-based cement (e.g., MTA) over the collagen matrix in a thin, homogeneous layer of approximately 2 mm. The cement should be placed below the cementoenamel junction. • Apply a flowable, light-cured glass ionomer cement. • Refresh the cavity walls with a diamond bur or aluminum oxide grit blasting. • Restore with an adhesive solution. Follow-up visits should be conducted after 3, 6, 12, 18, and 24 months, and then annually for 5 years. Clinical diagnostic tests should be performed according to the progression chart.

This clinical caution is supported by a 2022 systematic review and meta-analysis comparing regenerative endodontics with apexification in immature necrotic teeth. Although both approaches showed comparable periapical healing rates, regenerative endodontics demonstrated superiority in continued root development (root lengthening and wall thickening), without reliably restoring pulp sensibility, confirming that these procedures remain more reparative than truly regenerative [42].

4.4.3. Evidence Synthesis and Clinical Trends

The synthesis of the extracted data reveals a significant shift in endodontics toward an increasingly biological and technologically guided approach. For each theme addressed, the evidence was synthesized by evaluating the convergence of clinical results, the direct benefits for the practitioner, and the persisting limitations, beginning with diagnostics and imaging; results demonstrate increased accuracy through vascular vitality tests and CBCT. The primary benefit lies in the reduction of false diagnoses, although cost and radiation exposure (for CBCT) remain structural limitations. Next, instrumentation and irrigation, where innovations such as next-generation NiTi files and advanced irrigation activation show superior efficacy in cleaning complex root canal systems. The benefit is enhanced safety against instrument fracture and improved disinfection, while the main limitations include a steeper learning curve and higher equipment costs. Finally**,** root canal obturation and biomaterials, characterized by the emergence of bioceramics, which provide unprecedented sealing ability and biocompatibility. The primary benefit is the simplification of procedures and the promotion of periapical healing, whereas the difficulty of removal during endodontic retreatment remains a notable limitation.

Limitations of the Review: This narrative review has several limitations that should be acknowledged. First, the narrative nature of the study, while providing a broad overview, may introduce a degree of subjectivity in data selection and interpretation compared to a systematic review. Second, linguistic restrictions to articles published in English and French may have excluded relevant research published in other languages. Third, although four major databases were consulted, this selection does not guarantee absolute exhaustiveness of the global literature. Finally, a potential selection bias related to the inclusion criteria (such as the absence of conflict of interest or adherence to ethical standards) may have limited the number of studies analyzed.

5. Conclusion

The past decade has brought numerous innovations in endodontics, covering all stages of treatment: diagnosis, access cavity preparation, shaping, disinfection, and root canal obturation. Understanding of diseases and diagnostic capabilities have improved, with new tests, file systems, and obturation techniques. The choice depends on the case, preferences, and, above all, the practitioner's expertise. Continuing education remains essential to keep pace with technological advances and new techniques.

Author Contributions

Each author made a significant contribution to this review. AT and KB designed and conducted the study. AT, KB, and LD performed the electronic database searches, article selection, data extraction, and data synthesis, and drafted the first version of the manuscript under the supervision of FZR. All authors read, revised, and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Nivesh Krishna, R. and Pradeep, S. (2016) Recent Diagnostic Aids in Endodontics—A Review. *International Journal of Pharmaceutical and Clinical Research*, **8**, 1159-1162.

[2] Jindal, D., Raisingani, D., Sharma, M., Soni, D. and Dabas, H. (2014) Contemporary Diagnostic Aids in Endodontics. *Journal of Evolution of Medical and Dental Sciences*, **3**, 1526-1535. https://doi.org/10.14260/jemds/2014/2019

[3] Dias, A.R.G. (2021) Pulp Diagnostic. Flow Oximetry—Comparative Analysis between Healthy and Restored Teeth. https://repositorio.cespu.pt/bitstream/handle/20.500.11816/3751/MIMD_DISSERT_24624_AnaDias.pdf?sequence=1.

[4] Chandi, J.K., Rajapandy, S., Jahan, N. and Gill, S. (2021) Advances in Endodontics: A Brief Review. https://www.medicalandresearch.com/previous_view/451

[5] Singla, M.G. (2020) Magnification in Endodontics: A Review. *IP Indian Journal of Conservative and Endodontics*, **3**, 1-5. https://doi.org/10.18231/2456-8953.2018.0001

[6] Bahcall, J.K. (2013) Visualization in Endodontics. *European Journal of General Dentistry*, **2**, 96-101. https://doi.org/10.4103/2278-9626.112303

[7] Perrin, P., Neuhaus, K.W., Eichenberger, M. and Lussi, A. (2019) Influence of Different Loupe Systems and Their Light Source on the Vision in Endodontics. *Swiss Dental Journal SSO—Science and Clinical Topics*, **129**, 922-928. https://doi.org/10.61872/sdj-2019-11-565

[8] Jhajharia, K. (2016) Review Article: An Introduction to the Advanced Diagnostic Techniques in Endodontics. *Journal of Advanced Medical and Dental Sciences Research*, **4**, 95-99. https://jamdsr.com/uploadfiles/25.ADVANCEDDIAGNOSTICTECHNIQUESINENDODONTICS.20160510082103.pdf

[9] Pandey, D., Chaturvedi, P. and Shuklai, V. (2020) Recent Diagnostic Aids in Endodontics. https://iosrjournals.org/iosr-jdms/papers/Vol19-issue6/Series-4/A1906040105.pdf

[10] Rechenberg, D.K. and Zehnder, M. (2014) Molecular Diagnostics in Endodontics. *Endodontic Topics*, **30**, 51-65. https://doi.org/10.1111/etp.12057

[11] Ballester, B., Giraud, T., Ahmed, H.M.A., Nabhan, M.S., Bukiet, F. and Guivarc'h, M. (2021) Current Strategies for Conservative Endodontic Access Cavity Preparation Techniques—Systematic Review, Meta-Analysis, and Decision-Making Protocol. *Clinical Oral Investigations*, **25**, 6027-6044. https://doi.org/10.1007/s00784-021-04080-7

[12] Vats, S., Mishra, P. and Nikhil, V. (2021) Modern Access Cavity Concept: A Review. *International Journal of Research and Review*, **8**, 450-453.

[13] Maqbool, M., Noorani, T.Y., Asif, J.A., Makandar, S.D. and Jamayet, N.B. (2020) Controversies in Endodontic Access Cavity Design: A Literature Review. *Dental Update*, **47**, 747-754. https://doi.org/10.12968/denu.2020.47.9.747

[14] Shabbir, J., Zehra, T., Najmi, N., Hasan, A., Naz, M., Piasecki, L., *et al.* (2021) Access Cavity Preparations: Classification and Literature Review of Traditional and Minimally Invasive Endodontic Access Cavity Designs. *Journal of Endodontics*, **47**, 1229-1244. https://doi.org/10.1016/j.joen.2021.05.007

[15] Silva, E.J.N.L., Pinto, K.P., Ferreira, C.M., Belladonna, F.G., De-Deus, G., Dummer, P.M.H., *et al.* (2020) Current Status on Minimal Access Cavity Preparations: A Critical Analysis and a Proposal for a Universal Nomenclature. *International Endodontic Journal*, **53**, 1618-1635. https://doi.org/10.1111/iej.13391

[16] Connert, T., Leontiev, W., Dagassan-Berndt, D., Kühl, S., ElAyouti, A., Krug, R., *et al.* (2021) Real-Time Guided Endodontics with a Miniaturized Dynamic Navigation System versus Conventional Freehand Endodontic Access Cavity Preparation: Substance Loss and Procedure Time. *Journal of Endodontics*, **47**, 1651-1656. https://doi.org/10.1016/j.joen.2021.07.012

[17] Kishen, A., Peters, O., Zehnder, M., Diogenes, A. and Nair, M. (2016) Advances in Endodontics: Potential Applications in Clinical Practice. *Journal of Conservative Dentistry*, **19**, 199-206. https://doi.org/10.4103/0972-0707.181925

[18] Andrea, G.F. and Aissa, P. (2019) Evolution of Instruments in Endodontics-Literature Review. *International Journal of Dentistry and Oral Health*, **5**, 1-5. https://doi.org/10.16966/2378-7090.306

[19] Gavini, G., Santos, M.D., Caldeira, C.L., Machado, M.E.D.L., Freire, L.G., Iglecias, E.F., *et al.* (2018) Nickel-Titanium Instruments in Endodontics: A Concise Review of the State of the Art. *Brazilian Oral Research*, **32**, e67. https://doi.org/10.1590/1807-3107bor-2018.vol32.0067

[20] Matani, P., Chaudhary, D., Mathew, R. and Chouhan, B. (2019) Current Trends to Improve Root Canal Disinfection: A Review. *Chronicles of Dental Research*, **8**, 1-7. https://cdronline.org/college/wp-content/uploads/2019/05/1.Current-Trends-to-Improve-Root-Canal-Disinfection-%E2%80%93-A-Review.pdf

[21] Gohil, H., Mod, D.C., Shetty, V., Kanaparthy, A. and Goswami, H. (2020) Advances in Activation of Endodontic Irrigants. *Journal of Health Science and Medical Research*, **1**, 52-60. https://www.kjmt.co.in/wp-content/uploads/2015/08/13_Himadriba-converted.pdf.

[22] Lotfi, M., Ghasemi, N., Rahimi, S., Vosoughhosseini, S., Saghiri, M.A. and Shahidi, A. (2013) Resilon: A Comprehensive Literature Review. *Journal of Dental Research, Dental Clinics, Dental Prospects*, **7**, 119-130.

[23] Bansode, D.P.V., Pathak, D.S.D., Wavdhane, D.M.B. and Kale, D.D. (2018) Obturating Materials Present and Past: A Review. *IOSR Journal of Dental and Medical Sciences* (*IOSR-JDMS*), **17**, 27-33.

[24] Langalia, A.K., Dave, B., Patel, N., Thakkar, V., Sheth, S. and Parekh, V. (2015) Comparative Evaluation of Fracture Resistance of Endodontically Treated Teeth Obturated with Resin Based Adhesive Sealers with Conventional Obturation Technique: An *in Vitro* Study. *Journal of International Oral Health*, **7**, 6-12.

[25] Doumani, M., Habib, A., Khallof, R., Albakheet, M., Alghamdi, M. and Alowyyed, T. (2019) Activ GP System in Endodontics: A Review. *International Journal of Oral Care and Research*, **7**, 74-76. https://doi.org/10.4103/injo.injo_25_19

[26] Kulsum, M., Borthakur, B.J., B, S. and S, G. (2020) Water Expandable Root Canal Obturation System: A Review. *Dental Poster Journal*, **9**, 1-2. https://doi.org/10.15713/ins.dpj.073

[27] Trope, M., Bunes, A. and Debelian, G. (2015) Root Filling Materials and Techniques: Bioceramics a New Hope? *Endodontic Topics*, **32**, 86-96. https://doi.org/10.1111/etp.12074

[28] Simon, S. and Flouriot, A.C. (2021) BioRoot™ RCS a New Biomaterial for Root Canal Filling. https://www.septodont.ie/wp-content/uploads/2023/01/CSC13_BioRoot%E2%84%A2-RCS-a-new-biomaterial-for-root-canal-filling_14.pdf

[29] Sadique, M., Sv, R., Thomas, K., Dhanapal, P., Simon, E.P. and Shaheen, M.F. (2014) Evaluation of Efficacy of a Pulse Oximeter to Assess Pulp Vitality. *Journal of International Oral Health*, 6, 70-72.

[30] Janani, K., Palanivelu, A. and Sandhya, R. (2020) Diagnostic Accuracy of Dental Pulse Oximeter with Customized Sensor Holder, Thermal Test and Electric Pulp Test for the Evaluation of Pulp Vitality: An *in Vivo* Study. *Brazilian Dental Science*, **23**, 1-8. https://doi.org/10.14295/bds.2020.v23i1.1805

[31] Ghouth, N., Duggal, M.S., BaniHani, A. and Nazzal, H. (2018) The Diagnostic Accuracy of Laser Doppler Flowmetry in Assessing Pulp Blood Flow in Permanent Teeth: A Systematic Review. *Dental Traumatology*, **34**, 311-319. https://doi.org/10.1111/edt.12424

[32] Pandey, P., Aggarwal, H., Tikku, A.P., Singh, A., Bains, R. and Mishra, S. (2020) Comparative Evaluation of Sealing Ability of Gutta Percha and Resilon as Root Canal Filling Materials—A Systematic Review. *Journal of Oral Biology and Craniofacial Research*, **10**, 220-226. https://doi.org/10.1016/j.jobcr.2019.12.004

[33] Antony, D.P., Thomas, T. and Nivedhitha, M. (2020) Two-Dimensional Periapical, Panoramic Radiography versus Three-Dimensional Cone-Beam Computed Tomography in the Detection of Periapical Lesion after Endodontic Treatment: A Systematic Review. *Cureus*, **12**, e7736. https://doi.org/10.7759/cureus.7736

[34] Das, S. (2021) Echoes in Endodontics: A Comprehensive Review of Applications of Ultrasonography in Endodontics. *Journal of the West Bengal University of Health Sciences*, **1**, 62-70.

[35] Mohammadi, Z., Jafarzadeh, H., Shalavi, S. and Palazzi, F. (2017) Recent Advances in Root Canal Disinfection: A Review. *Iranian Endodontic Journal*, **12**, 402-406. https://doi.org/10.22037/iej.v12i4.17935

[36] Asiri, A.F. and Altuwalah, A.S. (2022) The Role of Neural Artificial Intelligence for Diagnosis and Treatment Planning in Endodontics: A Qualitative Review. *The Saudi Dental Journal*, **34**, 270-281. https://doi.org/10.1016/j.sdentj.2022.04.004

[37] Khanagar, S.B., Al-ehaideb, A., Maganur, P.C., Vishwanathaiah, S., Patil, S., Baeshen, H.A., *et al.* (2021) Developments, Application, and Performance of Artificial Intelligence in Dentistry—A Systematic Review. *Journal of Dental Sciences*, **16**, 508-522. https://doi.org/10.1016/j.jds.2020.06.019

[38] Aminoshariae, A., Kulild, J. and Nagendrababu, V. (2021) Artificial Intelligence in Endodontics: Current Applications and Future Directions. *Journal of Endodontics*, **47**, 1352-1357. https://doi.org/10.1016/j.joen.2021.06.003

[39] Lai, G., Dunlap, C., Gluskin, A., Nehme, W.B. and Azim, A.A. (2023) Artificial Intelligence in Endodontics. *Journal of the California Dental Association*, **51**, Article ID: 2199933. https://doi.org/10.1080/19424396.2023.2199933

[40] Karobari, M.I., Adil, A.H., Basheer, S.N., Murugesan, S., Savadamoorthi, K.S., Mustafa, M., *et al.* (2023) Evaluation of the Diagnostic and Prognostic Accuracy of Artificial Intelligence in Endodontic Dentistry: A Comprehensive Review of Literature. *Computational and Mathematical Methods in Medicine*, **2023**, Article ID: 7049360. https://doi.org/10.1155/2023/7049360

[41] Ducan, H.F. and Cooper, P.R. (2020) Clinical Approaches in Endodontic Regeneration—Current and Emerging Therapeutic Perspectives. *British Dental Journal*, **228**, 328. https://doi.org/10.1038/s41415-020-1364-6

[42] Alghamdi, F. and Alsulaimani, M. (2021) Regenerative Endodontic Treatment: A Systematic Review of Successful Clinical Cases. *Dental and Medical Problems*, **58**, 555-567. https://doi.org/10.17219/dmp/132181