j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

The Antimicrobial Characteristics of Some Natural Remedies in Root Canal Disinfection and Artificial Intelligence (AI): A Review

Abbas Mahdi Mohsin *[1], Rasha H. Jehad[2], Mustafa Waleed Ameen[3]

[1&2&3]*College of Dentistry, University of Baghdad, Baghdad, Iraq.*

abbasfsgv@gmail.com

Abstract The primary goal of root canal treatment (RCT) is to expel the presence of any necrotic or vital tissue, microbes and their byproducts from the canal space before press forward with the following steps of the RCT procedures. Although this is difficult to attain, various strives had been practiced by employing chemical and mechanical methods to eliminate as much microorganisms as possible and make the canal space valid for the obturation materials to be received. The aim of this review is to demonstrate some of what new remedies that could be used as root canal disinfectant by summarizing the recent studies regarding the efficacy of different natural products against the most persistence microbiota that could be responsible for most of the failures after RCT. A comprehensive search has been performed in English language on published resources using Pub Med, Google Scholar, and Research Gate databases from 2010 to Dec 2024 by using the keywords: "root canal irrigant", "cinnamon", "neem oil", "propolis", "triphala" and "Enterococcus faecalis". Thirty-two papers adopted in this review. Endnote reference management software was used for organization of citations. natural remedies demonstrated potential in reducing bacterial count especially when using synergism of various natural and chemical products, it shows remarkable effect in targeting resistant microbiota such Enterococcus faecalis nevertheless it must undergo comprehensive preclinical and clinical trials to substantiate the results before they can conclusively be recommended as intracanal irrigating solutions. Herbs are generally harmless when appropriately used, but they can be hazardous if taken incorrectly.

Crossref iob 10.36371/port.2025.4.8

Keywords: *Natural remedies; Root canal irrigant; Enterococcus faecalis; Neem oil*

INTRODUCTION

Teeth preservation by root canal treatment became very popular science the success of endodontic therapy starts to be predictable as most of the dentists start to understand endodontic pathology. Essentially, infection of the root canal system is the major source of apical periodontitis [1]. Microorganisms role in the pulp and periapical pathosis has been distinctly demonstrated. Since the success of any undergoing root canal treatment depend on the disinfection process, the mechanical methods of removal of the infected dentin alone is inadequate without irrigant application in which its penetration is facilitated by the mechanical preparation, and enhancing the decontamination of root canal system. nevertheless, the mechanical preparation leaves significant percentages of the root canal untouched, regardless the instruments used in the process [2]. This where the importance of antimicrobial irrigants and intra-canal dressing between appointment appear. The ultimate goals of any undergoing root canal treatment are to treat and prevent apical periodontitis [3]. The meaning of disinfection, is the removal of most if not all of microorganisms and their toxin from the root canal space in addition to the pulp tissue [4]. Enterococcus faecalis which is a facultative, anaerobic, gram-positive bacterium has been frequently found or recovered from secondary/persistent root canal infections [5]. this attributed to its tolerance to antimicrobials that applied during endodontic treatment [6]. In addition to the ability of E. faecalis to produce dense biofilms on the walls of root canal system make this microorganism has the capability to invade and enter the dentinal tubules and complexities in the root canal contributing to be recalcitrant to many endodontic disinfectants irrigant and intra-canal dressings leading to endodontic failure [7].

Since the most common irrigant used, sodium hypochlorite (NaOCl), has larger and heavier molecule, this will give suggestion that the smear layer lower the diffusion capability of the NaOCl to more than 50%. It is important to address the main drawbacks of NaOC1 irrigant solution; such as the cytotoxic effect to the peri-apical tissue; in addition to foul smell and taste when it applied in the mouth, furthermore, it cannot cover all bacterial strains, nor can full eliminate the smear layers [8]. In contrast natural remedies are considered an alternate treatment options for managing treatment problems in root canal system because of their ease of availability, antimicrobial performance, absence of microbial resistance, and safety with much lesser side effects [9]. Among the alternatives to synthetic products is herbal products that will be discussed in this review including extracts like propolis, triphala, neem oil, cinnamon. However, to the best of the Authors knowledge, there had been few efforts to summarize

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

studies that analyze the use of natural products as root canal disinfectant that will allow an easier analysis of the evidence.

Therefore, this review will shade the light about what new remedies that could be used as root canal disinfectant by summarizing the recent studies regarding the efficacy of different natural extracts against the most persistence microbiota that could be responsible for most of the failures after root canal treatment, and to overcome or reduce the drawbacks associated with the routinely used irrigants such as NaOCl compared with these natural entity, with lesser side effect and antimicrobial resistance and point out areas that need more research

Ideal requirement of root canal irrigants

Root canal irrigants should ideally have a wide antibacterial spectrum and eradicate necrotic pulp tissues. They should dissolve or inhibit the smear layer and inactivate endotoxins. Irrigants must be systemically safe, non-corrosive, and non-allergenic. They should be non-irritating to periapical tissues and effective as fungicides and germicides, even in the presence of blood. Ideal irrigants should have reduced surface tension, not stain teeth, or negatively affect dentin. They should not negatively affect the filler component, provide a good seal, be easy to apply, and be inexpensive [10].

Classification of root canal irrigants

Kandaswamy and Venkatesh babu, in 2010 classified the materials according to their composition into [11]**:**

- Chemical - dissolving the tissues, antimicrobial, chelating.
- Natural- Antibacterial agents.

Classification of Kale and Raut (2021) [12]**:**

- Herbal irrigants with antimicrobial property: e.g., Neem leaf extract, Garlic, Triphala, Morinda citrifolia, Propolis, Aloe vera, Green tea and Ginger.
- Herbal irrigants with chelating ability: e.g. Triphala extract, Neem leaf extract, Garlic (Allium sativum), Tulsi (Ocimum sanctum), Morinda citrifolia, Tea tree oil (Melaleuca alternifolia), Green tea
- Herbal irrigants with chelating and antibacterial properties: e.g., Morinda citrifolia, Neem leaf extract (Azadirachta indica), Triphala, Green tea, Tea tree oil (Melaleuca alternifolia), Garlic (Allium sativum)
- Herbal root canal irrigants capable to dissolve the tissue of the pulp: e.g, Sapindus mukorossi, Nepenthes khasiana digestive fluid, Garlic (Allium sativum).

Commonly used irrigants

The Irrigants currently used are, Sodium hypochlorite, Chlorhexidine, Ethylenediaminetetraacetic acid (EDTA) [13].

Sodium hypochlorite (NaOCl):

Most commonly used endodontic irrigant worldwide due to its antimicrobial capability and its effectiveness in dissolving tissue, having reduced viscosity aiding in its application in the root canal system, adequate half-life and lower price solutions are cost-effective. The antibacterial and the dissolving ability are dependent on the concentration of the solution. Unluckily, toxic effect is dependent on the concentration, rendering the main disadvantage of the sodium hypochlorite solution being the cytotoxic effect to the peri-apical tissue, in addition it leaves bad odor ant taste in the patient mouth and could cause corrosion to the metal objects. Furthermore, having the inability to cover the entire microbes and does not remove the smear layer entirely [14].

Chlorhexidine (CHX):

The solution has high activity against the microbes specially when using it at reduced PH [5.5 – 7], and its effect remains for long time after the solution is removed, as well it does not dissolve tissues. The Chlorhexidine molecules are highly reactive making it not recommended to be used in treatments having multiple irrigants, furthermore it is less effective when used against the Gram-negative microbes [14].

Ethylenediaminetetraacetic acid (EDTA):

Using a chelating agent during the instrumentation of calcified and narrow canals. Easily prepared 10 ml solution of EDTA 17% for a minute show complete removal of the smear layer from the walls of the canal enhancing the dentine permeability [14,15].

Disadvantages of Conventional Irrigants

There are some drawbacks of the chemical irrigants that are used commonly [16]:

- NaOCl have adverse reactions even in 1% concentration due to its caustic nature.
- EDTA when used with NaOCl expresses weak antibacterial effect due to the loss of the available free chlorine which lowers the efficacy of the NaOCl. As wall as this combination causes decalcification and erosion of the dentin which negatively affect the flexural strength of the dentine.
- CHX used in concentration similar to NaOCl, appears to have similar if not more cytotoxic effect. Additionally, it can react with the residual NaOCl inside the root canals and produce para-chloroaniline which considered potentially toxic, and carcinogenic

A. M. Mohsin, et al.. 2025, The Antimicrobial Characteristics of Some Natural Remedies in Root Canal Disinfection and Artificial Intelligence (AI): A Review. *Journal port Science Research*, 8(4), pp.386-395. https://doi.org/10.36371/port.2025.4.8

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

orange brown precipitate that could also cause discoloration.

- The chemical irrigants can be replaced to limit their use in pediatric patients when treating open apices [17].

Those irrigation solutions that commonly utilized today are synthetic chemicals and cannot exhibit all the ideal properties of an irrigation material alone. Considering the unwanted and inadequate properties of these existing solutions, the continuous elevation in the number of strains ability to resist the solutions, and the possible side effects of synthetic chemicals, it has been demonstrated that the natural alternatives for endodontic treatment practice are somehow promising.

Naturally Sourced Irrigant Remedies

Propolis extract:

Propolis or the term "bee glue" is the product of a honeybee in a mixed resin form of the mix of particular enzymes present in bee saliva and in beeswax. Researches indicated that propolis contains over 300 of active compounds. These active compounds can be utilized as antioxidants, as anti-inflammatory, as anticancer, as antibacterial, also antibiofilm [18]. Its mechanism of action may be dependent on the prohibition of the bacterial RNA-polymerase [19]. Extract of propolis at concentration 5.25% and NaOCl 5.25% both has no significant difference in inhibiting Staphylococcus aureus growth due to the flavonoid compound's present [20]. However, Setia et al in 2024 demonstrated that Propolis gave the least effective ability in elimination of the smear layer in comparison to Neem leaf extract, and orange oil because Propolis is highly viscous in nature due to the presence of resins, waxes and essential oils. This may explain the difficulty of introducing and removing the propolis from the root canal. This may further lead to increased surface tension by reducing the wet-ability of the surface of root canal [21].

Triphala:

Triphala is an Indian Ayurvedic natural treatment produced using the pulverized and dehydrated products of three plants used as a medicine: Terminalia bellerica, Emblica officinalis, and Terminalia chebula. It is biocompatible with PDL cells of humans and

has incredible effect against inflammation and antibacterial benefits [22]. Triphala contains various combinations like Tannin, Quinones, flavonoids, flavins, gallic acid, flavanols and vitamin C [24]. It can inactivate microbial adhesins, enzymes, and cell layer transport proteins. Quinones focuses on the microbial cell by following up on surface-uncovered adhesins, cell layer polypeptides, and cell layer bound compounds. Citrus extract, that present abundantly in Triphala, assist in eliminating the smear layer and exhibiting chelating behavior [22]. Keerthana et al in 2024 found that Triphala (20 µg/mL) displayed high antimicrobial effectivity, trailed by 3% NaOCl and Green tea extracts (20ug/mL) against F. nucleatum [25].

Neem:

Neem, or Azadirachta indica, is used in dentistry for its antimicrobial and antiviral properties. It contains various components, for example, Nimbidin, Nimbidinin, Sodium nimbidate, Nimbin, Nimbolide, Gedunin, Azadirachtin, Mahmoodin, Gallic corrosive, Margolonone and polysaccharides.Nimbidin, Nimbolide and Mahmoodin represses the cell layer synthesis of the microbe. and prevent adherence through altering the microbe's adhesion and capacity of microbial colonization. Neem extracts displayed a great antimicrobial activity against E. faecalis, as it contains large amount of antimicrobial phytoconstituents, for example, alkaloids, glycosides flavonoids, phenolic compounds, steroids, triterpenoids, carotenoids, and tetra triterpenoids. Butanolic extract of neem had more inhibition zone than ethanolic and ethyl acetic acid extracts. Studies show its effectiveness against microbes, its benefit as an intra-canal irrigant due to its antimicrobial action, and its antioxidant properties, displaying activity against both gram-positive and gram-negative microbes [26,27]. (Figure 1) demonstrate the natural existence of neem.

Figure 1: *Neem leaves*

Studies showed that neem give improved outcome and used as an alternative for intra-canal irrigant when combined with Triphala and CHX, however, when compared to different irrigant chemicals as silver diamine fluoride and NaOCl, it shows less efficacy [28, 29]

Cinnamon extract:

Cinnamon exists naturally as in (Figure 2) Cinnamon has gained popularity due to its antibacterial efficacy. It has shown effectiveness against S. mutans and E. faecalis. Cinnamon also exhibits activity against both gram-positive and gram-negative microorganisms. Vanillic, gallic, caffeic, pcoumaric, protocatechuic, and ferulic acids responsible for its antimicrobial efficacy [23,27]. Cinnamaldehyde and terpenes are the main constituents of cinnamon that provide the bactericidal action. Cinnamaldehyde that is 65-80% aromatic aldehyde is considered to be an active electronegative

A. M. Mohsin, et al.. 2025, The Antimicrobial Characteristics of Some Natural Remedies in Root Canal Disinfection and Artificial Intelligence (AI): A Review. *Journal port Science Research*, 8(4), pp.386-395. https://doi.org/10.36371/port.2025.4.8

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

component, whose effect prevent the action of amino acid decarboxylation through impeding the action of electron transfer, hence diminishing the level of cell glutathione in the microbial cell layer, resulting in energy shortage, thus end with death of the microbial cell. Terpenes action showed mainly by its effect on the cell layer, by damaging it because the membrane contains lipophilic compounds [30,31]. Gupta et al. in 2023 revealed that irrigant made of cinnamon extract exhibited the greatest antimicrobial efficacy against E. faecalis when compared to Neem, Cinnamon Miswak, and Apple juice vinegar. Cinnamon extracts showed better results as an irrigant in reducing Faecalis microorganism than 3% concentration of NaOCl, moreover cinnamon displayed lower time in time-kill research done against E. faecalis than other natural extracts. [28,32]

Limitation of the review

Figure 2: *Cinnamon beaks*

The majority of research on dental products formulated with herbal extracts has been conducted in Eastern countries with old processing mechanism, likely due to the cultural familiarity and abundant availability of medicinal herbs in these regions [33]-[34]. Nevertheless, most of these investigations are limited to in vitro studies and are frequently published in journals with relatively low scientific impact. Furthermore, there is a significant gap in the literature regarding the potential adverse effects of herbal-based dental products and luck of signal processing tools [35]-[36]. To address these limitations, future research should prioritize well-structured in vivo and longitudinal studies to better understand both the therapeutic potential and possible risks associated with these products and advance techniques [37]-[38].

Future Artificial Intelligence (AI) Prospective & Recommendations

Herbal and natural remedies have been investigated in endodontics for their potential to reduce inflammation and mitigate tissue irritation [39]-[40]. Bioactive constituents derived from these plants have shown antimicrobial properties against various oral pathogens, including *Streptococcus mutans*, *Candida albicans*, and others [41]-[42]. Despite these promising results, comprehensive preclinical and clinical evaluations are necessary to assess their safety, efficacy, potential interactions with dental materials, and possible adverse effects [43]-[44]. The therapeutic potential of natural products remains largely untapped and warrants further exploration [45]-[46]. Notably, such remedies may offer a cost-effective alternative in low-income regions where access to conventional endodontic care is limited [47]-[48]. Nonetheless, additional scientific evidence is essential before their integration into routine endodontic practice [49]-[50]. In addition, the antimicrobial characteristics of natural remedies for root canal disinfection is a field of growing interest, offering potential alternatives to conventional chemical agents like sodium hypochlorite [[51]-[52]. This will result in finding new techniques and methods using the Artificial Intelligence (AI) in this domain [53]-[54]. It is expected that the AI presents significant advantages in this field [55]-[56]. AI transforms the study of natural remedies for root canal disinfection from a labor-intensive, empirical process into a smart, predictive, and data-driven one [[57], [58] and [59]

The key advantages of using AI in this field can be stated by the following points [[60], [[61] and [62]:

1. Accelerated discovery and screening of natural compounds; this can be achieved by efficient sourcing and predictive modeling of bioactivity [63]-[64].
2. Optimization of remedy formulation which leads to synergistic combinations and balancing efficacy and safety [65], [[66] and [67].
3. Predictive modeling of clinical efficacy that can be implemented using biofilm penetration and personalized treatment planning [68]-[69].
4. Enhanced data analysis and research which the case in following uncovering hidden patterns and covering a systematic literature review [70]-[71].

This paper evaluating and applying natural remedies for root canal disinfection, AI and conventional methods represent two fundamentally different approaches [72]-[73]. While conventional methods rely on manual, empirical, and laboratory-based processes, AI leverages computational power and data to create a more efficient, predictive, and personalized workflow [74]-[75]. Table 1 gives a comparative table highlighting the advantages of each approach:

Table 1 *Highlighting the advantages of each approach*

Feature / Aspect	Conventional Methods	AI-Powered Solutions
Discovery of Compounds	• **Method:** Traditional methods involve manual literature reviews and bioassays (e.g., agar diffusion, MIC tests) on a limited number of known compounds	• **Method:** AI algorithms (e.g., machine learning, deep learning) perform virtual screening of vast databases of millions of chemical structures. • **Process:** Rapid,

A. M. Mohsin, et al.. 2025, The Antimicrobial Characteristics of Some Natural Remedies in Root Canal Disinfection and Artificial Intelligence (AI): A Review. *Journal port Science Research*, 8(4), pp.386-395. https://doi.org/10.36371/port.2025.4.8

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

Feature / Aspect	Conventional Methods	AI-Powered Solutions
	or extracts.• **Process:** Slow, labor-intensive, and resource-heavy. Requires physically testing each compound in the lab.• **Scope:** Limited to compounds that are already available or easily extracted, often missing novel candidates.	automated, and cost-effective. AI predicts antimicrobial activity based on molecular structure and properties without the need for physical testing.• **Scope:** Can discover entirely new and uncharacterized compounds, significantly expanding the pool of potential remedies.
Formulation and Optimization	• **Method:** A trial-and-error approach involving testing different concentrations and combinations of remedies in the lab to find an effective mix. • **Process:** Prone to inefficiency; researchers might miss an optimal synergistic blend. It's difficult to systematically explore all possible combinations. • **Outcome:** Formulations are often based on a few tested ratios, which may not be the most potent or the safest.	• **Method:** AI models analyze data on compound interactions to predict synergistic and antagonistic effects. • **Process:** AI can rapidly test millions of virtual combinations to identify the optimal balance between antimicrobial efficacy and minimal cytotoxicity. • **Outcome:** Formulations are data-driven and precisely optimized for maximum potency at the safest possible concentration.
Efficacy Assessment (In-vitro/In-vivo)	• **Method:** Direct observation and measurement in laboratory settings using techniques like scanning electron microscopy (SEM) to visualize biofilm disruption, or bacterial culturing to measure bacterial count.• **Process:** Time-consuming and subjective to observer interpretation. Results can vary between labs.• **Outcome:** Provides a "snapshot" of a remedy's effect under specific, controlled conditions. Difficult to extrapolate to the complex in-vivo environment.	• **Method:** AI can analyze vast amounts of imaging data (e.g., micro-CT, SEM) to quantify biofilm removal, dentin penetration, and bacterial load with high precision and objectivity.• **Process:** AI models create predictive simulations of a remedy's performance in complex, patient-specific root canal geometries.• **Outcome:** Provides a comprehensive, quantitative, and predictive understanding of a remedy's effectiveness, accounting for anatomical variability and biofilm complexity.
Personalization of Treatment	• **Method:** Clinicians choose remedies based on general best practices, personal experience, and broad scientific literature. • **Process:** One-size-fits-all approach. The same remedy and concentration are often used for different patients, regardless of the specific nature of their infection or root canal anatomy. • **Outcome:** Suboptimal results are possible due to a lack of personalization, leading to inconsistent treatment success rates.	• **Method:** AI integrates data from patient's dental imaging (CBCT), health records, and bacterial culture results to recommend a specific, optimized remedy. • **Process:** AI-powered systems can analyze the unique geometry of a patient's root canal and the specific pathogens present to select the most effective natural remedy and application technique. • **Outcome:** Enables personalized treatment plans that maximize the chance of complete disinfection and successful treatment, improving patient outcomes.
Data Handling and Knowledge Generation	• **Method:** Manual data collection and analysis from a limited number of experiments. Scientific knowledge is disseminated slowly through published papers. • **Process:** A slow, fragmented accumulation of knowledge. It's challenging for any single researcher to have a complete view of all findings. • **Outcome:** A relatively limited and dispersed body of knowledge. Difficult to identify overarching trends or complex correlations between a compound's properties and its antimicrobial effect.	• **Method:** AI systems can process and synthesize massive datasets from global research, clinical trials, and patient outcomes in real-time. • **Process:** AI can identify subtle, non-obvious patterns and correlations across different studies, leading to a deeper understanding of antimicrobial mechanisms. • **Outcome:** A comprehensive, integrated, and rapidly growing knowledge base that can inform future research and clinical decisions.
Disadvantages/Limitations	• **Disadvantages:** Time-consuming, resource-intensive, limited scope of discovery, prone to human error and subjectivity, difficult to achieve true personalization.	• **Disadvantages:** High initial investment in technology and expertise. Requires large, high-quality datasets for training. The "black box" nature of some AI models can make it difficult to understand the rationale behind a recommendation, which is a major concern for clinical application.

A. M. Mohsin, et al.. 2025, The Antimicrobial Characteristics of Some Natural Remedies in Root Canal Disinfection and Artificial Intelligence (AI): A Review. *Journal port Science Research*, 8(4), pp.386-395. https://doi.org/10.36371/port.2025.4.8

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

Conclusion

Herbs and other natural products that suggested in this review have several advantages, including ease of use, safety, ability to be stored, low cost, and absence of microbial tolerance. Natural irrigants acquired a place to be used as substitute or in conjugation with other types of irrigants in endodontic therapy. Their benefits combined with their safety and less irritability overcomes their harmful side effects. Researchers continued to seek a combination able to produce results capable of effectively removing microorganisms which is the nowadays vital goal and, in this review, highlighted several possible synergisms.

Scientific proof medicine is the corner stone of any manifested material needed to be used on or in the human body, therefore it must undergo comprehensive preclinical and clinical trials to substantiate the results before they can conclusively be recommended as intracanal irrigating solutions., some of these mentioned products already pass through this tunnel and give remarkable results.

Finally, AI transforms the study of natural remedies for root canal disinfection from a labor-intensive, empirical process into a smart, predictive, and data-driven one. It empowers researchers and clinicians to discover, formulate, and apply these natural agents more effectively, ultimately leading to improved clinical outcomes for patients.

REFERENCES

[1] Gomes, B. P. F. D. A., & Herrera, D. R. (2018). Etiologic role of root canal infection in apical periodontitis and its relationship with clinical symptomatology. Brazilian oral research, 32(suppl 1), e69. https://doi.org/10.1590/1807-3107bor-2018.vol32.0069

[2] Makeeva, M. K., Daurova, F. Y., Byakova, S. F., & Turkina, A. Y. (2020). Treatment of an endo-perio lesion with ozone gas in a patient with aggressive periodontitis: A clinical case report and literature review. Clinical, cosmetic and investigational dentistry, 447-464. https://doi.org/10.2147/CCIDE.S267933

[3] Siqueira Jr, J. F., & Rôças, I. N. (2022). Present status and future directions: Microbiology of endodontic infections. International endodontic journal, 55, 512-530. https://doi.org/10.1111/iej.13677

[4] Marek, E., Łagocka, R., Kot, K., Woźniak, K., & Lipski, M. (2020). The influence of two forms of chlorhexidine on the accuracy of contemporary electronic apex locators. BMC oral health, 20, 1-8. https://link.springer.com/content/pdf/10.1186/s12903-019-0994-z.pdf

[5] Bouillaguet, S., Manoil, D., Girard, M., Louis, J., Gaïa, N., Leo, S., ... & Lazarevic, V. (2018). Root microbiota in primary and secondary apical periodontitis. Frontiers in microbiology, 9, 2374. https://doi.org/10.3389/fmicb.2018.02374

[6] Ali, I. A., Cheung, B. P., Matinlinna, J., Lévesque, C. M., & Neelakantan, P. (2020). Trans-cinnamaldehyde potently kills Enterococcus faecalis biofilm cells and prevents biofilm recovery. Microbial Pathogenesis, 149, 104482. https://doi.org/10.1016/j.micpath.2020.104482

[7] Momenijavid, M., Salimizand, H., Korani, A., Dianat, O., Nouri, B., Ramazanzadeh, R., ... & Khosravi, M. R. (2022). Effect of calcium hydroxide on morphology and physicochemical properties of Enterococcus faecalis biofilm. Scientific reports, 12(1), 7595. https://doi.org/10.1038/s41598-022-11780-x

[8] Khoury, R. D., de Carvalho, L. S., do Nascimento, M. F. R., Alhussain, F., & Hasna, A. A. (2024). Endodontic irrigants from a comprehensive perspective. World Journal of Clinical Cases, 12(21), 4460. https://pmc.ncbi.nlm.nih.gov/articles/PMC11235474/

[9] Karobari, M. I., Adil, A. H., Assiry, A. A., Basheer, S. N., Noorani, T. Y., Pawar, A. M., ... & Scardina, G. A. (2022). Herbal medications in endodontics and its application—a review of literature. Materials, 15(9), 3111. https://doi.org/10.3390/ma15093111

[10] Bhanu, P., V., RamakrishnarajuK, JollingDiksha, Kashmeera, S., Turlapati. (2023). Herbal Endodontic Irrigants A Review, 5(2), 394. https://ijdmsrjournal.com/issue_certificate/Herbal%20Endodontic%20Irrigants%20%20A%20Review.pdf

[11] Kandaswamy, D., & Venkateshbabu, N. (2010). Root canal irrigants. Journal of Conservative Dentistry and Endodontics, 13(4), 256-264. https://journals.lww.com/jcde/fulltext/2010/13040/root_canal_irrigants.14.aspx

[12] Kale, P. P., & Raut, A. W. (2021). A proposed classification system for herbal endodontic irrigants. Journal of Conservative Dentistry and Endodontics, 24(3), 293-295. https://journals.lww.com/jcde/fulltext/2021/24030/a_proposed_classification_system_for_herbal.13.aspx

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

[13] Drews, D. J., Nguyen, A. D., Diederich, A., & Gernhardt, C. R. (2023). The interaction of two widely used endodontic irrigants, chlorhexidine and sodium hypochlorite, and its impact on the disinfection protocol during root canal treatment. Antibiotics, 12(3), 589. https://doi.org/10.3390/antibiotics12030589

[14] Alshammari, S. T. M., Turkistani, H. A., Almatar, Y. I., Alhuraish, A. M. A., Hefni, S. T., Bagabir, R. A., ... & Alfari, A. Y. (2022). An overview on endodontic irrigation solution role in management. International Journal of Pharmaceutical Research and Allied Sciences, 11(1-2022), 17-20. https://doi.org/10.51847/hQTG6i8ZFl

[15] Tekin, B., & Demirkaya, K. (2020). Natural irrigation solutions in endodontics. https://gulhanemedj.org/articles/doi/gulhane.galenos.2020.902

[16] Jain M, Nagaraja S, V Shruthi, Deveswaran, Shruthika. (2024). A Review on Endodontic Irrigants: Herbal versus Conventional. Int J Heal Sci Res ,14(11),109. https://doi.org/10.52403/ijhsr.20241111

[17] Aktaş, N. A. G. E. H. A. N., Öztaş Kırmızı, N. U. R. H. A. N., Özçelik, B. E. R. R. İ. N., & Oyardı, Ö. Z. L. E. M. (2023). Evaluation of the antimicrobial efficacy of herbal alternatives and ozone in root canal disinfection. INDIAN JOURNAL OF APPLIED RESEARCH, 13(2). https://avesis.gazi.edu.tr/publication/showdocument/6194ce1d-3092-43fe-bca6-f9cd4aab4e2a

[18] Aini, F. N., & Adiningrat, A. (2021, January). Challenge in Propolis Biocompatibility as a potential medicament in dental medicine. In 4th International Conference on Sustainable Innovation 2020–Health Science and Nursing (ICoSIHSN 2020) (pp. 237-247). Atlantis Press. https://www.atlantis-press.com/proceedings/icosihsn-20/125951258

[19] Chermut, T. R., Fonseca, L., Figueiredo, N., de Oliveira Leal, V., Borges, N. A., Cardozo, L. F., ... & Mafra, D. (2023). Effects of propolis on inflammation markers in patients undergoing hemodialysis: A randomized, double-blind controlled clinical trial. Complementary Therapies in Clinical Practice, 51, 101732. https://doi.org/10.1016/j.ctcp.2023.101732

[20] Firdaus, I., Aryanto, M., Paath, S.L., Hayati, N. (2024) The Effectiveness of Propolis Antibacterial Against Staphylococcus aureus as an Alternative to Root Canal Irrigation. Sriwij J Dent, 5(1), 21–6. https://sjd-fk.ejournal.unsri.ac.id/index.php/sjd/article/view/51

[21] Setia, R., Bajaj, N., Bhola, M., & Brar, G. S. (2023). Comparative evaluation of smear layer removal efficacy of neem leaf extract, propolis, and orange oil when used as endodontic irrigants: An in vitro scanning electron microscopic study. Contemporary Clinical Dentistry, 14(2), 128-134.

[22] Bhavani, G. D., Rathod, T., Parveen, N., Tirupathi, P., Dharavattu, P., Sekhar, V. S. S. K., ... & Utkarsh, K. (2023). Assessment of the antimicrobial effectiveness of herbal root canal irrigants (Propolis, triphala, and aloe vera) and chlorhexidine against Enterococcus faecalis. Cureus, 15(7).

[23] Nabavi, S. F., Di Lorenzo, A., Izadi, M., Sobarzo-Sánchez, E., Daglia, M., & Nabavi, S. M. (2015). Antibacterial effects of cinnamon: From farm to food, cosmetic and pharmaceutical industries. Nutrients, 7(9), 7729-7748. https://doi.org/10.3390/nu7095359

[24] Mookhtiar, H., Hegde, V., Shanmugasundaram, S., Chopra, M. A., Kauser, M. N., & Khan, A. (2019). Herbal irrigants: A literataure review herbal irrigants; a new era in endodontics: Literature review. Int J Dent Med Sci Res, 3(2), 15-22. https://www.ijdmsr.com/wp-content/uploads/2019/03/C331522.pdf

[25] Chandran, K., Sridhar, D., John, B. M., Jayakumar, S., Arumugam, K., & Ponnusamy, P. (2024). Comparison of antimicrobial efficacy of green tea extract and Triphala as root canal irrigants against Fusobacterium nucleatum using real-time polymerase chain reaction–An in vitro study. Endodontology, 36(1), 44-48.

[26] Mustafa, M. (2016). Antibacterial efficacy of neem (Azadirachta indica) extract against Enterococcus faecalis: an in vitro study. J Contemp Dent Pract, 17(10), 791-794.

[27] Panchal, V., Gurunathan, D., & Muralidharan, N. P. (2020). Comparison of antibacterial efficacy of cinnamon extract, neem extract as irrigant and sodium hypochlorite against Enterococcus fecalis: an: in vitro: study. Indian Journal of Dental Research, 31(1), 124-128. https://journals.lww.com/ijdr/fulltext/2020/31010/comparison_of_antibacterial_efficacy_of_cinnamon.23.aspx

[28] Gupta, A., Gupta, R. K., Kaul, B., Shah, S. G., & Gandhi, S. G. Comparative Evaluation of Anti-Microbial Efficacy of Phytomedicinal Extracts with Chemical Root Canal Irrigants against Enterococcus Faecalis: An in Vitro Study. https://ijmpr.in/uploads/article/IJMPR43203-893-909.pdf

[29] Raj, S., Sharma, A., Dhinsa, K., Saha, S., Yadav, G., & Sharma, P. (2024). Comparative Evaluation of Microbial Reduction Using Silver Diamine Fluoride, Azadirachta indica (Neem) and Sodium Hypochlorite as Root Canal Irrigants after Biomechanical Preparation in Uniradicular Canals: An In Vivo Study. International Journal of Clinical Pediatric Dentistry, 17(6), 625.

[30] Yanakiev, S. (2020). Effects of cinnamon (Cinnamomum spp.) in dentistry: A review. Molecules, 25(18), 4184. https://doi.org/10.3390/molecules25184184

[31] Abbaszadegan, A., Dadolahi, S., Gholami, A., Moein, M. R., Hamedani, S., Ghasemi, Y., & Abbott, P. (2016). Antimicrobial and cytotoxic activity of Cinnamomum zeylanicum, calcium hydroxide, and triple antibiotic paste as root canal dressing materials. Journal of Contemporary Dental Practice, 17(2), 105-113. 10.5005/jp-journals-10024-1811

[32] Mahdi, A., Al-Huwaizi, H., & Abbas, I. (2018). A comparative evaluation of antimicrobial activity of the ethanolic extract of Cinnamomum zeylanicum and NaOCl against oral pathogens and against swabs taken from nonvital teeth-An in vitro study. International Journal of PharmTech Research, 10, 39-47.

[33] Ali Akram Abdul-Kareem, Waleed Ameen Mahmoud Al-Jawher "A Hybrid Domain Medical Image Encryption Scheme Using URUK and WAM Chaotic Maps with Wavelet–Fourier Transforms" Journal of Cyber Security and Mobility, Pages 435-464, 2023.

[34] Maryam I Mousa Al-Khuzaay, Waleed A Mahmoud Al-Jawher "New Proposed Mixed Transforms: CAW and FAW and Their Application in Medical Image Classification" International Journal of Innovative Computing, Volume 13, Issue 1-2, Pages 15-21, 2022.

[35] AHM Al-Heladi, WA Mahmoud, HA Hali, AF Fadhel "Multispectral Image Fusion using Walidlet Transform" Advances in Modelling and Analysis B, Volume 52, Issue 1-2, Pages 1-20, 2009.

[36] Ali Akram Abdul-Kareem, Waleed Ameen Mahmoud Al-Jawher "WAM 3D discrete chaotic map for secure communication applications" International Journal of Innovative Computing, Volume 13, Issue 1-2, Pages45-54, 2022.

[37] W. A. Mahmoud, J J. Stephan and A. A. Razzak "Facial Expression Recognition Using Fast Walidlet Hybrid Transform" Journal port Science Research و Volume3, No:1, Pages 59-69, 2020.

[38] Qutaiba K Abed, Waleed A Mahmoud Al-Jawher "A Robust Image Encryption Scheme Based on Block Compressive Sensing and Wavelet Transform" International Journal of Innovative Computing, Volume 13, Issue 1-2, Pages 7-13, 2022.

[39] Zahraa A Hasan, Suha M Hadi, Waleed A Mahmoud "Time domain speech scrambler based on particle swarm optimization" Pollack Periodica, Volume 18, Issue 1, Pages 161-166, 2023.

[40] Rasha Ali Dihin, Waleed A Mahmoud Al-Jawher, Ebtesam N AlShemmary "Diabetic retinopathy image classification using shift window transformer" International Journal of Innovative Computing, Volume 13, Issue 1-2, Pages 23-29, 2022.

[41] SMR Taha, WA Mahmood "New techniques for Daubechies wavelets and multiwavelets implementation using quantum computing" Facta universitatis-series: Electronics and Energetics 26 (2), 145-156, 2013.

[42] QK Abed, WAM Al-Jawher " Anew Architecture of Key Generation Using Dwt For Image Encryption With Three Levels Arnold Transform Permutation", Journal Port Science Research 5 (3), 166–177-166–177, 2022.

[43] Lamyaa Fahem Katran, Ebtesam N AlShemmary, Waleed AM Al-Jawher "A Review of Transformer Networks in MRI Image Classification" Published 2024-07-18, Al-Furat Journal of Innovations in Electronics and Computer Engineering, PP. 148-162, 2024.

[44] Abbas Hasan Kattoush, W Al-Jawhar, A Ghodayyah "Multiwavelet computed Radon-based OFDM transceiver designed and simulation under different channel conditions" Journal of Information & Computing Science, Volume 5, Issue 2, Pages 133-145, 2010.

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

[45] A. Barsoum and Entather Mahos Waleed. A. .Mahmoud "Fuzzy Wavenet (FWN) classifier for medical images" Al-Khwarizmi Engineering Journal, Volume 1, Issue 2, Pages 1-13, 2005.

[46] W. A. Mahmoud Z Jalal & N. K. Wafi "A New Method of Computing Multi-wavelets Transform using Repeated Row Preprocessing." Al-Rafidain Engineering Journal, Vol. 12, Issue 2, PP. 21-31., 2004.

[47] RA Dihin, E AlShemmary, W Al-Jawher "Diabetic Retinopathy Classification Using Swin Transformer with Multi Wavelet", Journal of Kufa for Mathematics and Computer 10 (2), 167-172, 2023

[48] Mutaz Abdulwahab and Hadeel Al-Taai Waleed Ameen Mahmoud "New Fast Method for Computing Wavelet Coefficients from 1D up to 3D" , proceedings of the 1st Int. Conference on Digital Communication and computer Application, Jordan, Pages 313-323, 2007.

[49] Hamid M Hasan, AL Jawher, Majid A Alwan "Face recognition using improved FFT based radon by PSO and PCA techniques" International Journal of Image Processing (IJIP), Volume 6, Issue 1, Pages 26-37, 2012.

[50] Waleed A Mahmoud Al-Jawher, Sarah H Awad "A proposed brain tumor detection algorithm using Multi wavelet Transform (MWT)" Materials Today: Proceedings, Volume 65, Pages 2731-2737, 2022.

[51] Walid Amin Mahmoud "Computation of wavelet and multiwavelet transforms using fast fourier transform" Journal Port Science Research, Volume 4, Issue 2. Pages 111-117, 2021.

[52] AHM Al-Helali, Waleed A. Mahmoud, HA Ali "A Fast personal palm print authentication Based on 3d-multi–Wavelet Transformation", TRANSNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY, Vol. 2, Issue 8, 2012.

[53] Waleed A Mahmoud, Afrah Loay Mohammed Rasheed " 3D Image Denoising by Using 3D Multiwavelet" AL-Mustansiriya J. Sci, Volume 21, Issue 7, Pages 108-136, 2010.

[54] Waleed A. Mahmoud, MS Abdulwahab, HN Al-Taai: "The Determination of 3D Multiwavelet Transform" IJCCCE, vol. 2, issue 4, 2005.

[55] Waleed Al-Jawhar, Abbas Hasan Kattoush, Sulaiman M Abbas, Ali T Shaheen "A high performance parallel Radon based OFDM transceiver design and simulation" Digital Signal Processing, Volume 18, Issue 6, Pages 907-918, 2008

[56] Maryam I Al-Khuzaie, Waleed A Mahmoud Al-Jawher "Enhancing Medical Image Classification: A Deep Learning Perspective with Multi Wavelet Transform" Published: 2023-11-11, Journal Port Science Research, Vol. 6, Issue 4, PP. 365-373, 2023.

[57] Ali Akram Abdul-Kareem, Waleed Ameen Mahmoud Al-Jawher "Uruk 4D discrete chaotic map for secure communication applications" Journal Port Science Research, Volume 5, Issue 3, Pages 131-142, 2023.

[58] Ali Akram Abdul-Kareem, Waleed Ameen Mahmoud Al-Jawher "Hybrid image encryption algorithm based on compressive sensing, gray wolf optimization, and chaos" Journal of Electronic Imaging, Volume 32, Issue 4, Pages 043038-043038, 2023.

[59] Hamid M Hasan, Waleed A Mahmoud Al-Jawher, Majid A Alwan "3-d face recognition using improved 3d mixed transform" Journal International Journal of Biometrics and Bioinformatics (IJBB), Volume 6, Issue 1, Pages 278-290, 2012.

[60] Hamid M Hasan, AL Jouhar, Majid A Alwan "Face recognition using improved FFT based radon by PSO and PCA techniques" International Journal of Image Processing (IJIP), Volume 6, Issue 1, Pages 26-37, 2012.

[61] Ebtesam N. AlShemmary and Waleed A. Mahmoud Al-Jawher Rasha Ali Dihin "Automated Binary Classification of Diabetic Retinopathy by SWIN Transformer" Journal of Al-Qadisiyah for computer science and mathematics (JQCM), Volume 15, Issue 1, Pages 169-178, 2023.

[62] Rasha Ali Dihin, Ebtesam N AlShemmary, Waleed AM Al-Jawher "Wavelet-Attention Swin for Automatic Diabetic Retinopathy Classification" Baghdad Science Journal, Volume 21, Issue 8, Pages 2741-2741, 2024.

[63] Qutaiba K Abed, Waleed A Mahmoud Al-Jawher "Optimized color image encryption using arnold transform, URUK chaotic map and GWO algorithm" Journal Port Science Research, Volume 7, Issue 3, Pages, . 219-236, 2024.

j. port. sci. res.
ISSN: 2616-7441 (Online)
ISSN: 2616-6232 (Print)
ISSN: 2616-7220 (USB)
INTERNATIONAL IDENTIFIER FOR SERIALS

Journal port Science Research
Available online www.jport.co
Volume 8, issue 4. 2025

[64] Waleed A Mahmoud Al-Jawher, Shaimaa A Shaaban "K-Mean Based Hyper-Metaheuristic Grey Wolf and Cuckoo Search Optimizers for Automatic MRI Medical Image Clustering" Journal Port Science Research, Volume 7, Issue 5, Pages 109-120, 2024.

[65] Walid A Mahmoud, Majed E Alneby, Wael H Zayer "Multiwavelet Transform and Multi-Dimension -Two Activation Function Wavelet Network Using for Person Identification" IJCCCE, Volume 11, Issue 1, Pages 46-61, 2011.

[66] Waleed Ameen Mahmoud, Omama Razzak "Speech recognition using new structure for 3D neural network" 2010, University of Technology, 1st Computer Conference, Pages . 161-171, ttps://cs.uotechnology.edu.iq/index.php/112-about-dept-en/394-conf-2010

[67] Waleed A. Mahmoud, Ahmed S Hadi "Systolic Array for Realization of Discrete Wavelet Transform" Journal of Engineering, Volume 13, Issue 02, Pages 1368-1377, 2007.

[68] Afrah U Mosaa, Waleed A Mahmoud Al-Jawher "A proposed Hyper-Heuristic optimizer Nesting Grey Wolf Optimizer and COOT Algorithm for Multilevel Task" Journal Port Science Research, Vol. 6, PP. 310,317, 2023.

[69] Maryam I Mousa Al-Khuzaie, Waleed A Mahmoud Al-Jawher "Enhancing Brain Tumor Classification with a Novel Three-Dimensional Convolutional Neural Network (3D-CNN) Fusion Model" Journal Port Science Research, Volume 7, Issue 3, Pages 254-267, 2024.

[70] Waleed A. Mahmud Al-Jawher, Talib M. J. Abbas Al-Talib, R. Hamudi A. Salman "Fingerprint Image Recognition Using Walidlet Transform" Australian Journal of Basic and Applied Sciences, Australia, 2012.

[71] Ammar A Sakran, Suha M Hadi, Waleed A Mahmoud Al-Jawher "Advancing DNA Signal Processing: Integrating Digital and Biological Nuances for Enhanced Identification of Coding Regions" 11-11-2023, Journal Port Science Research, Volume, 6, Issue 4, Pages 374-387, 2023.

A. M. Mohsin, et al.. 2025, The Antimicrobial Characteristics of Some Natural Remedies in Root Canal Disinfection and Artificial Intelligence (AI): A Review. *Journal port Science Research*, 8(4), pp.386-395. https://doi.org/10.36371/port.2025.4.8