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Moringa Oleifera as an Alternative Endodontic Irrigant: A Review of Its Phytochemical, Pharmacological Profile and Applications

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ABSTRACT

Understanding the fundamental role of endodontic irrigants is key to identifying safer, more biocompatible and effective alternatives. Efficient root canal irrigation is critical for eliminating microbial contamination, removing the smear layer and ensuring thorough disinfection during endodontic procedures. However, the documented cytotoxicity of conventional irrigants, combined with the growing emphasis on regenerative approaches in endodontics, has intensified the search for natural, biocompatible solutions.

Moringa oleifera (Mor O.), known for its antimicrobial, anti-inflammatory and antioxidant properties, has emerged as a promising herbal candidate. This mini-review explores the phytochemical composition and endodontic potential of Mor O. leaf and seed extracts, focusing on their antibacterial effects, smear layer removal capabilities and influence on interradicular dentin roughness.

Mor O. leaves are rich in bioactive compounds such as isothiocyanates, flavonoids, tannins, phenols and saponins. Particularly, 70% ethanolic extracts have demonstrated superior antimicrobial efficacy due to higher concentrations of phenolic acids and flavonoids. Extraction methods, solvent type and preparation temperature significantly influence the concentration and stability of these compounds. Conversely, Mor O. seeds contain high levels of fatty acids and benzyl isothiocyanate, contributing to antimicrobial action and potential lubricating benefits within the root canal system.

This review is based on a comprehensive literature search across four electronic databases: PubMed, Scopus, Web of Science and the Cochrane Library. Studies were included if they focused on Moringa oleifera in endodontic applications or synthesis. No time or language restrictions were applied. Articles outside the scope of endodontics were excluded.

Although in vitro findings support the efficacy of Mor O. extracts, clinical validation is still required. Further studies are necessary to standardize extraction protocols and concentrations and to confirm their safety and effectiveness compared to conventional irrigants.

Keywords: Moringa Oliefera, sustainable endodontic irrigant, smear layer removal, antibacterial activity, biocompatibility

1. Introduction

Microbial eradication is one of the main objectives of root canal treatment and ensures proper disinfection while preserving the integrity of the tooth. Root canal irrigation plays a crucial role in achieving these objectives, facilitating the removal of debris, the dissolution of the smear layer and effective antimicrobial action[1]. While mechanical instrumentation is a key step in this process, it alone is insufficient for fully eliminating microorganisms[2]. The main goals of endodontic irrigants are the ability to dissolve the smear layer by both organic and inorganic components lubricating the root canal and disrupting biofilm[3]. Additionally, irrigants help in obtaining dentin irregularities and enhancing the sealing ability of root canal filling[4].

Mechanical effectiveness depends on the irrigant's ability to generate sufficient streaming force within the canal system and reach areas inaccessible to mechanical instrumentation[5]. Chemical effectiveness depends on the concentration of antimicrobial ingredients, surface tension and irrigant's interaction duration[6]. The biological function of an irrigant is its ability to effectively eradicate intraradicular pathogens. An ideal irrigant should achieve this without causing harmful effect. Presently, no endodontic solution used for irrigation can be regarded as optimal. However, combining selected irrigation products dramatically contributes to successful treatment outcomes[7].

Conventional irrigants, sodium hypochlorite (NaOCl) and chlorhexidine gluconate (ChX) are examples of widely used endodontic irrigants due to their high antimicrobial effectiveness. However, these products often have limitations, including cytotoxicity and limited ability to remove the smear layer and the potential for bacterial resistance. When these are used at high concentrations, sodium hypochlorite shows high cytotoxicity to periapical tissues. Chlorhexidine, in addition to being expensive, has reduced antimicrobial activity when it encounters the organic components of dentin. One of the effective protocols is using ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl), which meet the main goal of endodontic irrigants[8]. Unfortunately, previous research showed that increasing exposure to EDTA caused erosion of dentin[4,9,10]. Accordingly, resultant exposed collagen fibers are disintegrated when NaOCl is used after EDTA.

Therefore, there is great demand for substances that can be used as endodontic irrigants that are effective and present low cytotoxicity[11,12]. There has been growing interest in exploring alternative natural compounds, such as Mor O., for use as endodontic irrigants. This review summarizes the experimental findings on the potential of Mor O. leaf, seed and root extracts as endodontic irrigants, specifically focusing on their effects on smear layer removal, antibacterial activity, biocompatibility and roughness of the root canal surface.

Numerous herbs were recognized for their medicinal action caused by their extracted phytochemical components[13]. Moringa oleifera (Mor.O.) or "Miracle Tree," one of those, has abundant benefits. Commonly referred to as the drumstick or horseradish tree, it is part of the Moringaceae family. It is abundant in the tropical regions of Asia, with a high content of active chemical agents with antibacterial and antifungal properties[14,15]. Mor O. is known for its high tolerance to extremely dry weather conditions, causing its high abundance due to easy cultivation. Moringa parts, such as their leaves, seeds and roots, are utilized due to their various medicinal benefits[16].

This review aimed to determine whether Mor O. leaves and seeds could be used as an alternative to chemical endodontic irrigants based on their crucial functions: antimicrobial activity, effect on interardicular dentin (IRD) roughness and smear layer removal.

1.1. Phytochemical analysis of Mor O. parts (root, leaves and seeds) and their extracts

There is a relation between Moringa phytochemical components and their pharmacological effects. Previous studies have reported several groups of compounds unique to each part of Mor O. Mor O. leaf extract contains alkaloids, isothiocyanates, phenols, saponins and tannins. It is considered a remedy for many inflammations at a relatively low cost. High amounts of phenols and tannins that are conjugated with amino acids and gelatin produce an antimicrobial effect[17]. The most abundant isothiocyanate has been investigated due to its important antibacterial and anti-inflammatory actions[18-20]. Unextracted isothiocyanate are unstable whereas those isolated from Mor O. extracts are very stable at room temperature[21]. However, several factors affect the biological activities of Mor. O. leaf extract. First, the solvent used for the extraction method[22]. Methanol, ethanol, butanol and ethyl acetate were used as solvents for flavonoid to affect its extraction from different parts of Mor O[23-25].

A higher content of flavonoids, for example, was found in a 70% ethanol Moringa leaf extract after heating for 2 hours[26]. The second is a method used for the preparation of Moringa leaf extract. The flavonoid composition and concentration of Moringa leaves differ according to extraction and treatment method. It was reported that abundant phenols were obtained using sonication in maceration technique[27]. Third, a temperature at which the extract is prepared. It was shown that phenols decrease with the rise in temperature[28]. Aqueous and other organic solvent separation of Moringa leaf extracts was reported to be safe for therapeutic activities[29].

The Egyptian Scientific Society of the Moringa Trees prepares leaf extracts with both aqueous and alcoholic-based solvents. Washed dried leaves are ground and the resultant powder is dispersed in distilled water in a 1:1 (w/v) ratio. This mixture is kept for 12 hours. Then, a 100% plant extract containing compounds solution is filtered. The obtained extract is then heated to 50 ºC for 15 min[30].

Another method for producing watery Mor O. leaf extracts was also reported. The leaves are cleaned, dehydrated, sieved and powdered. Then, the obtained powder is homogenized using hot water (1gm: 2.5mL ratio) and stirred for 24 hours at room temperature. The extract is obtained by filtration and evaporated in an oven. Then, the extract is diluted by adding distilled water according to usage[31]. The ethanolic extract of moringa leaf can be obtained by mixing powder with ethanol (1kg:1000mL) for 48h followed by filtration two times. Then, the extract is kept away from light and in a cold place at 4oC[32]. The extract is evaporated and diluted with ethanol according to the required concentration. Another simple way of preparing watery and alcoholic moringa extracts was reported in previous research[33]. Moringa leaf powder in a ratio of 1:10 (gm: ml, respectively) of 99% ethanol (for alcoholic extract) or water (for aqueous

extract) was mixed and soaked for 48 hours. Then, both extracts were collected and filtered.

A study was conducted to examine phytochemical compounds in leaf extracts prepared using water and ethanol solvents through the maceration process. Different concentrations of distilled water and ethanolic alcohol, 100% of distilled water, while 30 and 70% of ethanol were used to prepare Mor O. leaf extract and kept for 3 days, then evaporated. Finally, the prepared extract was preserved in a refrigerator[34]. It was found that 70% ethanol moringa leaf extract showed high concentrations of different phytochemical phenolic acids that have anti-inflammatory and antibacterial effects[35,36]. Furthermore, FTIR spectroscopy analysis showed functional groups of alcohols, isocyanates and phenols. Conversely, a moderate quantity of flavonoids and low phenols, alkaloids and saponins were detected in aqueous Mor O. leaf extract[35].

Additionally, Leone et al. reported more flavonoids, phenolic acids, saponins, alkaloids and alkaloids in 70% ethanol extract[17]. Khalid et al. also demonstrated that 70% ethanolic leaf extract is more effective than aqueous extract, likely due to the presence of phenols, flavonoids, tannins and saponins in great percentages[37]. This was attributed to hydroxyl groups that can bind polar compounds such as flavonoids and alkaloid components of Mor O[38]. On the other hand, seeds of Mor O. contain 19 to 47% oil and are rich in fatty acids, saponins, flavonoids, polyphenols, proanthocyanidins, rutin and ascorbic acid. Based on this description[39,40]. Active substances, especially benzyl isothiocyanate, which are found in large amounts, interfere with bacterial enzyme synthesis and cell membranes inhibiting bacterial growth[41]. Also, it was reported that unclean, infected water could be purified and sterilized from bacteria to 99% by using moringa seed powder. It could attract impurities, causing them to settle down. This is why such sustainable powder could be used for purification instead of toxic chemicals. Moreover, usage of the oil, if it is used as an endodontic irrigant might have additional privileges over the leaf extract because it is highly valued as a lubricant[42].

To obtain moringa seed oil extract, a cold-pressing technique can be used. First, the seeds are cleaned, shelled and pressed mechanically without heat. This method effectively preserves phytochemical compounds without damaging them. The paste mix is diluted in distilled water in a ratio of 1:5, filtered and preserved until used[43,44]. However, the ethanol extract of Mor. O seeds could be obtained by maceration. Peeled fresh seeds are dried, then mashed using a blender and sieved to become a smooth powder. The powder, then it is mixed in enough 96% ethanol until it is completely submerged. Then, it is protected from light while stirring for 24 hours. Obtained filtrate is evaporated until a thick extract with a concentration of 100% is obtained[45]. The oil is typically diluted or emulsified for easier application even in the root canal system (37.5%, 50%, 62.5% and 75%)[46].

Based on previous phytochemical reports for Mor O. leaves and seeds and their use in research, these parts are promising and actually used as endodontic irrigants (especially leaves). Although the other moringa parts (root, stem and flower) might have effective compounds and be used for medical purposes, experiments to examine their efficacy as a herbal irrigant have not yet been conducted on them. Hence, these parts were not included in our review.

1.2. Moringa Oleifera application in endodontics

One of the most important criteria for an irrigant is its antibacterial efficacy. Numerous studies have demonstrated that both leaf and seed extracts of Mor O. particularly when prepared with ethanol or methanol, possess significant antimicrobial activity, especially against Enterococcus faecalis, a common and resilient root canal pathogen[47]. The extracts contain a rich array of bioactive compounds such as flavonoids, saponins, alkaloids, tannins and terpenoids, each contributing to bacterial elimination through various mechanisms ranging from disrupting bacterial cell membranes to inhibiting essential metabolic functions.

In some studies, methanolic extracts of Mor O. leaves surpassed the antibacterial efficacy of 2% chlorhexidine[47], while 75% and 100% aqueous leaf extracts were found to be as effective as 5.25% sodium hypochlorite (NaOCl)[48]. Moreover, combining Mor O. extracts with lower concentrations of NaOCl produced a synergistic effect, enhancing bacterial eradication while reducing the cytotoxic risks associated with higher NaOCl levels[49]. Similarly, ethanolic seed extracts at higher concentrations (up to 75%) displayed robust activity against E. faecalis, surpassing even NaOCl in some evaluations[46,50].

However, not all findings were uniform-some comparisons with MTAD and chlorhexidine showed Mor O. to be less potent, underscoring the importance of standardized formulations and testing conditions[51]. Beyond antimicrobial properties, Mor O. extracts have also shown promising results in removing the smear layer-a critical step for ensuring the cleanliness of the root canal system. Studies comparing Mor O. with conventional irrigants like EDTA and NaOCl reported comparable or superior smear layer removal at certain concentrations. In one investigation, 5% aqueous Mor O. leaf extract outperformed 2.5% NaOCl and showed similar efficacy to EDTA.50 Other studies using SEM analysis observed that both alcoholic and aqueous Mor O. preparations widened dentinal tubules and exposed collagen fibers, indicating a chelating effect that facilitates smear layer removal[33].

The impact on intraradicular dentin roughness further supports Mor O.'s potential. Enhanced surface roughness is beneficial for improving the micromechanical bonding of root canal sealers. Use of 100% aqueous Mor O. leaf extract significantly increased dentin surface roughness, yielding results on par with the conventional NaOCl-EDTA regimen[9].

2. Conclusion

Moringa oleifera leaf extracts-and to a lesser extent, seed extracts-have shown the greatest potential for endodontic use. Despite the lack of standardized extraction methods, their phytochemical profiles support their effectiveness as herbal irrigants. Demonstrating antimicrobial activity, smear layer removal, biocompatibility and minimal impact on dentin roughness, Moringa extracts present a promising natural alternative to conventional irrigants. Their low cytotoxicity and sustainable origin further support their relevance in modern, eco-conscious endodontics. Future studies should focus on optimizing extraction methods, exploring synergistic combinations and validating clinical efficacy through long-term research.

3. Recommendation

70% ethanol moringa leaf extract could be used for

further vitro and in-vivo studies due to its great efficacy in anti-inflammatory and antimicrobial effects. Also, based on phytochemical analysis, 70 % ethanol-based moringa leaf extract is suitable for smear layer removal.

Further studies should emphasize the potential of Moringa's antibacterial properties, the removal of smear layers and the biocompatibility of various parts with different solvent-based extracts in both in vitro studies and clinical trials within root canals.

4. Declarations

4.1. Ethics approval and consent to participate

Not applicable.

4.2. Consent for publication

Not applicable.

4.3. Competing interests

The authors declare that they have no competing interests"

4.4. Acknowledgement

Not applicable.

4.5. Author contributions

Conceptualization: SM. Collection of data: NY and SM. Writing the original draft: NY, EMF and SM. Review and editing: NY, EMF and SM. Final critical revision: EMF and SM.

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