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Potential of Red Dragon Fruit Peel Extract (*Hylocereus polyrhizus*) as a Natural Irrigant for Root Canal Smear Layer Removal: A Narrative Review

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ABSTRACT

Smear layer is a layer of organic and inorganic debris that forms on the root canal walls during mechanical instrumentation in root canal treatment. This layer can prevent irrigation solutions from penetrating properly and affect the adaptation of root canal filling materials. Conventional irrigation solutions, such as sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA), have several limitations, including toxicity, tissue irritation, changes in the mechanical properties of dentin, and differences in their ability to remove smear layer components. These limitations have led to the search for natural irrigation alternatives that may offer better biocompatibility and help improve root canal cleaning. Red dragon fruit peel extract (*Hylocereus polyrhizus)* contains bioactive compounds, such as saponins and tannins, which have antibacterial and antioxidant properties. Therefore, it has the potential to be developed as a natural root canal irrigant. This narrative review aims to examine the potential of red dragon fruit peel extract as a natural irrigant for removing the smear layer from root canals. The literature review focuses on its potential to remove the smear layer by examining the phytochemical content and biological activities of the extract. The available literature shows that red dragon fruit peel extract has activity against several microorganisms associated with root canal infections. However, research on its effectiveness in removing the smear layer is still limited. Further studies are therefore needed to evaluate its smear layer removal effectiveness, optimal concentration, mechanism of action, and biocompatibility before it can be considered for use as a natural root canal irrigant.

Keywords: red dragon fruit peel extract; *Hylocereus polyrhizus*; root canal irrigation; saponins; smear layer

INTRODUCTION

The 2023 Indonesian Health Survey (Survei Kesehatan Indonesia/SKI) reported that the prevalence of dental and oral health problems reached 56.9%, while only 11.2% of those affected received treatment from healthcare professionals [1]. These figures indicate that dental and oral health problems remain a major concern in Indonesia, while the use of dental healthcare services is still relatively low [1]. Among these conditions, certain pulp diseases may require endodontic treatment, including root canal treatment (RCT), depending on the patient's clinical condition [2].

Root canal treatment (RCT) aims to remove infected pulp tissue, reduce the number of pathogenic microorganisms in the root canal system, and prevent infection or reinfection [3]. Mechanical instrumentation during RCT produces a layer known as the smear layer, which consists of fine dentin particles and organic and inorganic tissue debris covering the root canal walls and dentinal tubules [4]. The presence of this layer can provide a medium for microbial growth and prevent filling materials from penetrating the dentinal tubules. It can also increase the risk of microleakage, which may lead to reinfection and reduce the long-term success of endodontic treatment [5].

In endodontic practice, sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) remain commonly used irrigation solutions [6]. Sodium hypochlorite (NaOCl) serves as the main irrigant because it effectively dissolves organic tissue and has broad-spectrum antimicrobial activity. However, it cannot remove the inorganic components of the smear layer. In contrast, EDTA acts as a chelating agent that binds to calcium ions to dissolve the inorganic components of the smear layer. However, it has no antibacterial activity and cannot dissolve organic tissue [7]. The use of NaOCl and EDTA at high concentrations or over extended periods may cause periapical tissue irritation, damage to dentin, and a reduction in dentin structural integrity [7,8]. These limitations have encouraged the development of natural irrigation solutions that are more biocompatible and safer for surrounding tissues while being able to remove the smear layer without damaging the dentin structure [9].

The use of herbal ingredients as root canal irrigation solutions is based on their potential for lower toxicity, better biocompatibility, and antibacterial and antioxidant activities. These properties may support root canal disinfection without causing significant adverse effects on periapical tissues [10]. One natural material with potential for development as an alternative irrigant is red dragon fruit peel (*Hylocereus polyrhizus*). Red dragon fruit peel contains various bioactive compounds, including saponins, flavonoids, tannins, and anthocyanins, which have antibacterial and antioxidant properties [11]. Saponins are amphiphilic compounds that act as natural surfactants. They can reduce the surface tension of irrigation solutions, emulsify smear layer particles, and help dissolve necrotic tissue and debris in the root canal [12,13]. Phenolic compounds and organic acids may also interact with the mineral components of dentin [12,14]. Meanwhile, tannins have astringent properties that affect proteins and may help disrupt the bond between the smear layer and the dentin surface [11]. These characteristics provide a theoretical basis for the potential use of bioactive compounds in red dragon fruit peel to support root canal cleaning and smear layer removal [15].

The biological activities of red dragon fruit peel extract have been reported in various studies, including its antibacterial activity against microorganisms associated with oral diseases [14]. Previous research has shown that the extract exhibits antibacterial activity against Enterococcus faecalis, a microorganism commonly associated with root canal infections [14]. Other studies have also explored the use of red dragon fruit peel extract as a root canal irrigant based on its antibacterial activity against Staphylococcus aureus [16]. These findings suggest that red dragon fruit peel has potential for further development in endodontics, particularly as a source of natural irrigation materials [14]. However, research on its use as an irrigant has mainly focused on its antibacterial activity rather than its ability to remove the smear layer.

Smear layer removal requires materials that can interact with both its organic and inorganic components [15]. Several natural materials have been reported to have potential as smear layer removal agents, leading to continued research into their use as alternative irrigation solutions [17]. However, evidence regarding the ability of red dragon fruit peel extract to remove the smear layer from root canals remains limited. Therefore, a review of its phytochemical content, biological activities, potential mechanisms of action, and available research evidence is needed to assess its potential as a natural irrigant for smear layer removal in root canal treatment.

SMEAR LAYER AND ITS ROLE IN ROOT CANAL TREATMENT

The smear layer refers to a thin layer of particles consisting of dentin, dentinal tubules, tissue remnants, and bacteria that forms on the dentin surface after preparation and instrumentation procedures, such as those performed during endodontic or restorative treatment [18]. This layer is a thin debris film approximately 1–5 μm thick, with an amorphous, irregular, and granular structure. It covers the surface of the root canal walls and blocks the openings (orifices) of the dentinal tubules [6]. The smear layer consists of two main components: organic and inorganic components [19]. The organic components include remnants of vital or necrotic pulp tissue, blood cells, collagen, odontoblastic processes, microorganisms, and their metabolic products, including endotoxins [20]. Meanwhile, the inorganic components consist of calcified dentin particles, calcium hydroxyapatite, and tricalcium phosphate [19,21]. This composition indicates that the smear layer contains both organic and inorganic materials, which require different approaches for removal.

The presence of the smear layer has several significant negative effects on the success of root canal treatment [6]. It acts as a nutrient substrate that supports the adhesion, colonization, proliferation, and survival of pathogenic microorganisms within the dentinal tubules [6,14]. The smear layer also forms a physical barrier that prevents disinfecting irrigation solutions and intracanal medicaments from penetrating and exerting their effects within the dentinal tubules [22]. In addition, this layer interferes with the contact, adaptation, and adhesion of filling materials (sealers) to the dentin walls, thereby increasing the risk of post-obturation microleakage [20]. Thorough removal and elimination of the smear layer before obturation are essential to improve dentin permeability, maximize intracanal disinfection, and ensure a hermetic seal of the root canal system [20,21,23].

CONVENTIONAL IRRIGANTS IN ROOT CANAL TREATMENT

Conventional irrigation agents play an important role in supporting the cleaning and disinfection of the root canal system during endodontic treatment [24].

Irrigation solutions are used to help remove pulp tissue remnants, instrumentation debris, and microorganisms that cannot be completely reached by mechanical instruments [16,25]. An ideal irrigation agent is expected to have broad-spectrum antimicrobial activity, dissolve organic tissue, help remove the smear layer, and have minimal toxicity to periapical tissues [24].

Sodium hypochlorite (NaOCl), at concentrations ranging from 0.5% to 5.25%, is the most commonly used conventional irrigation solution and is considered the gold standard in root canal treatment [6,21]. NaOCl has broad-spectrum antiseptic and antimicrobial properties and is highly effective in dissolving remnants of both vital and necrotic pulp tissue [26]. However, its main limitations are its inability to remove the inorganic components of the smear layer, its toxicity to periapical tissues if extruded through the apical foramen, and its potential to damage the micromechanical properties and structure of dentin [21,27]. The use of NaOCl at high concentrations or over extended periods may cause irritation of the periapical tissues, as well as damage to and a reduction in the structural integrity of dentin [27].

To address the limitations of NaOCl in eliminating the inorganic components of the smear layer, a 17% ethylenediaminetetraacetic acid (EDTA) solution is widely recommended as a chelating agent [28]. EDTA binds to calcium ions in dentin hydroxyapatite, allowing it to dissolve inorganic substances and open the orifices of the dentinal tubules [14,21]. However, EDTA cannot dissolve organic tissue and does not have sufficient antibacterial activity. In addition, using EDTA at high concentrations or over extended periods may lead to extensive dentin demineralization and erosion, reduce the calcium-to-phosphorus (Ca/P) ratio, and decrease the microhardness of the root canal walls [29].

CHARACTERISTICS AND PHYTOCHEMICAL CONTENT OF RED DRAGON FRUIT PEEL

Red dragon fruit (*Hylocereus polyrhizus*) belongs to the Kingdom Plantae, Division Spermatophyta, Subdivision Angiospermae, Class Dicotyledonae, Order Caryophyllales, Family Cactaceae, Genus Hylocereus, and Species *Hylocereus polyrhizus* [30]. Red dragon fruit peel is a by-product of fruit processing that has the potential to be used as a natural source for the development of healthcare products. Anatomically, the peel consists of an exocarp composed of a double epidermal layer and a mesocarp containing water-rich parenchyma tissue, mucilage cells, calcium oxalate crystals, sclereids, and tracheids [31]. The presence of water-rich parenchyma tissue and mucilage cells indicates that the peel contains high levels of water and mucilaginous components, while its other structures reflect the complexity of the red dragon fruit peel matrix [31]. Red dragon fruit peel has been reported to contain higher levels of polyphenols, bioactive compounds, and antioxidant activity than the fruit flesh [32].

Red dragon fruit peel (*Hylocereus polyrhizus*) contains various secondary metabolites that may be useful as natural ingredients, including alkaloids, flavonoids, and phenolic compounds [11]. Phytochemical screening of red dragon fruit peel ethanol extract has shown positive results for alkaloids, flavonoids, anthraquinones, cardenolides, bufadienolides, and coumarins. Meanwhile, thin-layer chromatography analysis has indicated the presence of alcohols, phenols, steroids, and essential oils [33]. Red dragon fruit peel also contains bioactive compounds such as phenolics, betacyanins, and betaxanthins. The levels of these compounds may vary depending on the drying method used during material processing [34].

The presence of these various bioactive compounds indicates that red dragon fruit peel has the potential to be developed as a natural ingredient for healthcare applications, including dentistry [33]. Phenolic compounds and flavonoids contribute to antioxidant activity through their ability to neutralize free radicals, while betacyanins and betaxanthins give red dragon fruit its characteristic color and possess antioxidant activity [34,35]. Secondary metabolites, such as alkaloids and other compounds, may also contribute to the various biological activities of red dragon fruit peel extract. This diversity of phytochemical compounds makes red dragon fruit peel a potential source of natural compounds for the development of plant-based materials [33].

BIOLOGICAL ACTIVITIES OF RED DRAGON FRUIT PEEL EXTRACT

Red dragon fruit peel extract (*Hylocereus polyrhizus*) has potential biological activities, particularly antibacterial and antioxidant effects, which may support its development as a natural root canal irrigant. These activities include antimicrobial, antioxidant, and anti-inflammatory properties [11]. Antibacterial activity is one of the main biological properties of this extract. In vitro studies have shown that it can inhibit the growth of Enterococcus faecalis, a major pathogen associated with persistent infections and endodontic treatment failure [11,16]. Previous research reported that red dragon fruit peel extract at concentrations of 20%, 40%, 60%, 80%, and 100% could inhibit the growth of E. faecalis, with the highest antibacterial activity observed at a concentration of 100% [7]. Agar diffusion tests have confirmed that red dragon fruit peel ethanol extract produces significant inhibition zones against E. faecalis. At higher concentrations, the extract produces inhibition zones with diameters comparable to or greater than those of standard irrigation solutions, such as sodium hypochlorite (NaOCl 5%) and chlorhexidine (CHX 2%) [11,16]. In addition to E. faecalis, this extract has also been shown to inhibit other endodontic pathogens, including Staphylococcus aureus [32].

The disinfecting activity of red dragon fruit peel extract is mediated by the synergistic effects of its bioactive secondary metabolites [16,36,37]. Alkaloids interfere with the formation of peptidoglycan in

bacterial cell walls and disrupt intercellular communication, which is essential for biofilm formation [16,38]. Triterpenoids interact with transmembrane proteins in the outer bacterial cell membrane, disrupting porin structures. This can interfere with the regulation of nutrient transport and eventually lead to cell death [11,16]. Flavonoids form complexes with extracellular proteins and cell wall lipids, causing protein denaturation and damage to the plasma membrane, while tannins coagulate cellular protoplasm and bind proteins irreversibly [32].

In addition to its antimicrobial properties, red dragon fruit peel extract has strong antioxidant activity that helps neutralize reactive oxygen species (ROS). Evaluation using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method showed that the ethanol extract had a highly promising inhibitory concentration (IC50), mainly due to its high content of polyphenols, flavonoids, tannins, and betalain/ betacyanin pigments [37]. The major chemical constituents identified through GC-MS analysis, such as pentadecanoic acid (10.90% of the total peak area) and lupeol, have also been associated with significant anti-inflammatory and cytoprotective effects [36]. These antioxidant properties are important for neutralizing oxidative stress in periapical tissues [36].

Red dragon fruit peel extract (*Hylocereus polyrhizus*) also shows potential anti-inflammatory activity. This activity is supported by bioactive compounds, including flavonoids, alkaloids, saponins, and tannins, which may influence inflammatory processes [39]. An experimental study in white rats showed that red dragon fruit peel extract could inhibit protein denaturation and reduce the number of leukocytes in inflammatory exudates, with the effects increasing as the dose increased [40]. Inhibition of protein denaturation may help limit changes in protein structure caused by inflammation, while a reduction in leukocyte numbers in inflammatory exudates indicates an effect on the inflammatory response [40].

THE POTENTIAL OF RED DRAGON FRUIT PEEL EXTRACT IN SMEAR LAYER REMOVAL

The main potential of red dragon fruit peel extract (*Hylocereus polyrhizus*) for smear layer removal is based on its bioactive secondary metabolites, particularly saponins [36]. Saponins are glycoside compounds with a characteristic amphiphilic structure consisting of hydrophilic (polar) groups and hydrophobic (non-polar) aglycones, allowing them to act as natural surfactants [20,22,41]. The presence of saponins can significantly reduce the surface tension of irrigation solutions [41]. This reduction is important because it facilitates the penetration of the irrigation solution into narrow and complex areas of the root canal, particularly the apical third [20,22]. Through micellization, the hydrophobic groups of saponins bind to and emulsify the organic debris matrix of the smear layer, such as necrotic tissue remnants and lipid components. Meanwhile, the hydrophilic groups interact with water molecules, allowing the debris to become trapped and flushed out of the root canal system [14,41].

In addition to the surfactant properties of saponins, red dragon fruit peel extract is rich in phenolic compounds and organic acids, such as phenolic acids, which may act as calcium-chelating agents [36]. When these weak acids come into contact with the dentin surface, they ionize and release hydrogen ions. These hydrogen ions react with dentin hydroxyapatite, disrupting calcium bonds and forming soluble calcium complexes [14,31,38]. This natural demineralization process dissolves the inorganic components of the smear layer and softens the dentin surface in a controlled manner, thereby opening the dentinal tubule orifices. This process may offer an alternative to synthetic chelating solutions, such as 17% EDTA, which are often associated with excessive dentin erosion [14,21].

The multidimensional synergistic effects of saponins as surfactants in removing organic debris and organic or phenolic acids in chelating calcium to dissolve inorganic components may provide thorough cleaning of the root canal walls [14,38]. Red dragon fruit peel extract also contains secondary metabolites, such as alkaloids, flavonoids, and tannins, which may inhibit bacterial growth by disrupting cell membrane integrity and interacting with cellular proteins [41]. Flavonoids can affect bacterial cell membrane function, while tannins can bind to proteins and interfere with cellular activity [42]. These antibacterial properties may support root canal disinfection by inhibiting microorganisms that contribute to endodontic infections [16,32]. The combination of surface tension reduction, the dissolution of organic and inorganic components, strong antimicrobial activity, and potential biocompatibility makes red dragon fruit peel extract a promising natural alternative irrigant for smear layer removal and root canal disinfection [16,21,32,36].

CONCLUSIONS

Red dragon fruit peel extract (*Hylocereus polyrhizus*) has the potential to assist in smear layer removal due to its saponin content, which acts as a natural surfactant. Saponins can reduce surface tension and improve the wetting and penetration of the irrigation solution into the dentinal tubules. In addition, phenolic compounds and organic acids may help dissolve inorganic components by binding calcium ions, while saponins may help emulsify organic debris. Further research is needed to confirm the extract's effectiveness, mechanism of action, optimal concentration, and biocompatibility before it can be used in clinical practice.

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