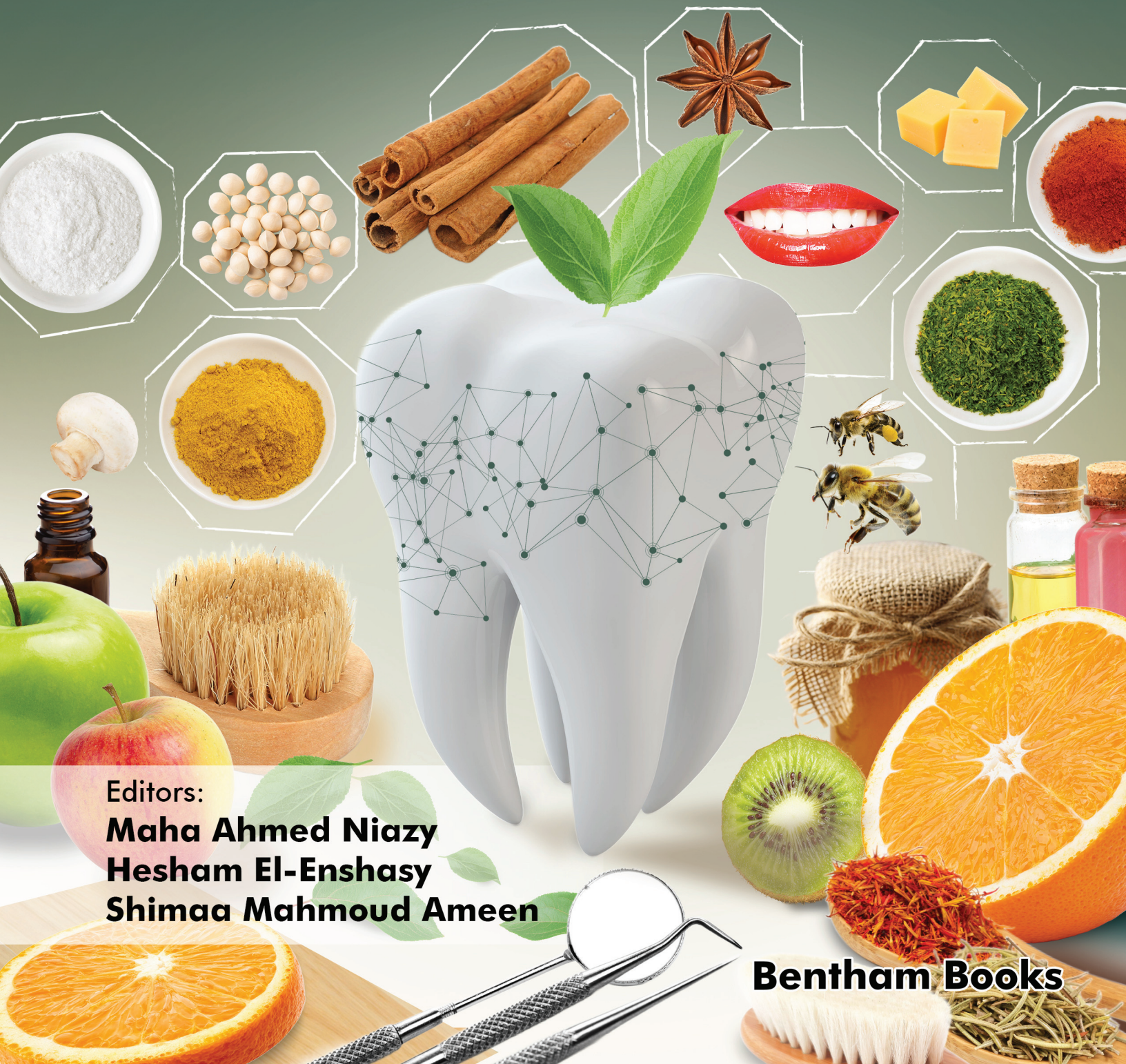
NATURAL CONSERVATIVE DENTISTRY:
AN ALTERNATIVE APPROACH TO SOLVE RESTORATIVE PROBLEMS



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FOREWORD

Natural Conservative Dentistry is a comprehensive guide that explores the use of herbs in the prevention and treatment of various dental challenges. The global need for alternative treatment of oral diseases that are safe, effective, and economical arises from the rise in disease incidence, increased resistance of pathogens to currently used chemotherapeutics, opportunistic infections in immunocompromised individuals, and financial consideration. Despite the availability of different approaches for the discovered drugs, plants remain the main reservoirs of natural medicine.

The book delves into traditional herbal remedies in oral healthcare and highlights the scientific evidence supporting their efficacy. It starts with an introduction to the principles of herbal medicine and the importance of natural products in promoting dental health. It then provides an overview of restorative dentistry's most commonly used herbs, including their active constituents, mechanisms of action, and potential side effects.

The book's subsequent chapters discuss the role of herbal products in providing alternative therapy to restorative conditions, such as caries, loss of dental tissues like enamel, dentin, and cementum, as well as dental hypersensitivity, tooth discolouration, and issues encountered with bonding to the tooth tissues. The authors provide a detailed analysis of the scientific evidence supporting the use of herbal remedies in each of these conditions and practical recommendations for their safe and effective use. The book also covers other topics related to herbal products in dental conditions, such as the formulation of herbal preparations, the manipulation of herbal products, and comparative analysis between selected herbal remedies and conventional synthetic agents.

Overall, the book is invaluable for dental professionals, researchers, and students interested in integrating herbal medicine into their clinical practice and research. It provides a comprehensive overview of the current knowledge of the use of herbal products in dental health and offers practical guidance for their safe and effective use.

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PREFACE

First, I sincerely thank the authors for their hard work and dedication in compiling this vital resource. This book will inspire other dentists to explore the use of herbal products in restorative dentistry and contribute to the advancement of our profession.

We are pleased to introduce this innovative book on using herbal products in restorative dentistry. As academic and practicing dentists, we constantly seek effective treatment methods, and this book offers valuable insights into using natural remedies to promote dental health. To develop this book, the authors have done an outstanding job of compiling the latest research on the use of herbal products in restorative dentistry and presenting it in a clear and accessible manner.

Throughout its chapters, the book provides practical guidance on how to incorporate these products into your practice, with information on the formulation of herbal preparations, the manipulation of herbal products, and comparative analysis between selected herbal remedies and conventional synthetic agents.

We are confident that this book will be a valuable addition to the library of any dentist interested in incorporating herbal medicine into their practice.

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DEDICATION

This book is dedicated to all professional dentists who defy the status quo and continuously strive to provide their patients with the best possible care using natural and sustainable remedies.

As the authors of this book, we hope that the knowledge shared in these pages inspires you to incorporate herbal remedies into your practice and benefit patients in their restorative dental treatments.

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CHAPTER 1

Natural Anti-cariogenic Agents

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Abstract: Tooth decay is primarily caused by demineralization resulting from acids secreted by bacteria, especially *Streptococcus mutans* and *lactobacillus*, which ferment dietary carbohydrates. This occurs in plaque biofilms, which attach to the surfaces of the tooth and become laden with bacteria. Thus, over time, dental caries result from the interaction of three main contributing factors: a diet containing carbohydrates, caries-producing bacteria, as well as sensitive tooth structure. The use of an antibacterial strategy for treating caries has evolved as a result of (1) identifying certain types of the oral microbiome as the main cariogenic flora and (2) increasing the knowledge of the specific ecology of these cariogenic florae. Combined with this concept, control, and prevention of caries have been sought by reducing the number of bacteria colonizing. Reducing bacterial populations or completely eradicating them from the oral flora would provide an additional reason to prevent dental caries. Several undesirable side-effects of conventional antimicrobial agents include tooth discoloration and the emergence of bacterial resistance. These side effects stimulate the search for alternative natural anti-microbial agents.

Keywords: Acid production inhibition, Bacterial adherence, Control of biofilm, Dental plaque, Extracellular-Polysaccharides synthesis, Ecology, Fruit extract, GTF, Glucosyltransferases, Herbal extract, Natural antimicrobial agents, Pathogenesis of caries, Probiotics, Plant extract, *Streptococcus mutans*, Sweetener, Sugar substitute, Spices.

INTRODUCTION

Dental caries is caused by the interaction of specific bacteria and their metabolites with components of saliva and diet containing carbohydrates on tooth surfaces. The synthesis of extracellular polysaccharides in the biofilm matrix, acid production, and the low pH at the tooth-biofilm interface are the main modulating

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animus factors regulating the pathogenesis of caries. While many micro-organisms may be included in the pathogenesis of the carious process. *Streptococcus mutan*s have a significant role in the formation of toxic biofilm [1 - 4]. This bacterium efficiently metabolizes sucrose for the synthesis of extracellular polysaccharides *via* the activity of glucosyltransferases (Gtfs), and Fucosyltransferases bind to the surface of saliva-coated tooth enamel. Bacteria tenaciously adhere to the dextran-coated surface. It is both acid-producing and acid-resistant.

The extracellular polysaccharides are mainly composed of glucans that are formed by Gtfs enzymes in salivary pellicles (almost all GtfC) and that bind to the bacterial cell surface (almost all GtfB) among sucrose. *In situ* formed glucan provides the following functions binding sites for *Streptococcus mutans*, the matrix holds microbial cells together to form co-aggregated cell clusters called micro-colonies [5]. If these microcolonies are regularly exposed to a diet containing carbohydrates and not removed from the tooth surface (especially sucrose), *Streptococcus mutans* and other acid-producing and tolerant bacteria in the biofilm will ferment sucrose to organic acids [5].

Chemotherapeutic Strategies to Control Biofilm

Biologically active chemical agents on biofilm components may be promising for preventing or reducing the frequency of the caries process. Such components may have the following mechanism: (1) block Gtfs adhesion to the salivary pellicle, (2) inhibit the secretion of extracellular-polysaccharides, (3) modify the composition of extracellular polysaccharides matrix, (4) inhibit bacterial colonization, (5) disrupt acid formation and adaptation process, (6) suppress the growth of oral microorganisms, and (7) modify the biofilm ecology and biochemistry. Chlorhexidine, triclosan, and essential oils (*e.g*., Listerine) are broad-spectrum nonspecific microbicides, they are the most commonly used types. The research focused on chemotherapeutic strategies focused on decreasing the expression of *Streptococcus mutans* virulence factors without the destruction of the pathogen.

Strategies to control the biofilm are based on the disturbance of EXPs synthesis on the surfaces. Extracellular polysaccharides matrix may act as an adsorbent, thereby reducing antimicrobials that can interact with biofilms. Therefore, extracellular polysaccharide-inhibiting materials enhance the efficacy of antibacterial agents on plaque biofilm [6].

Effect of Natural Agents on Caries-producing Pathogens and *Streptococcus mutans* Physiology

Natural agents remain the main source of promising therapeutics for the management of human diseases [7, 8]. Research on the use of natural agents to inhibit or cure dental caries received limited regard in medicine. The biological effects of natural agents are as follows:

(i) Sugar substitute.

(ii) Inhibit exopolysaccharide synthesis.

(iii) Inhibit intracellular-polysaccharide synthesis, and decrease acid production.

(iv) Inhibition of bacterial adherence.

(v) Antibacterial effect: inhibit metabolism and growth of acid-producing and tolerated species.

(vi) Enhance salivary buffering capacity.

(vii) Improve acid resistance of enamel.

Classifications of Natural Anti-cariogenic Agents

1-Plant extract

2-Spices

3-Fruit extract

4-Sweetener

5-Natural micro-organisms (probiotics)

PLANT EXTRACTS

Due to their high content of antimicrobial agents, medicinal plants are useful in the management of different diseases, including bacterial diseases. Many phytochemicals, including antimicrobials, are derived from edible plants and have been shown to have antibacterial properties against *Streptococcus mutans* [8].

CHAPTER 2

Natural Enamel Remineralizing Agents

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Abstract: Non-invasive management of initial enamel lesions using novel remineralizing agents has become the main goal of modern dentistry. Herbs and natural sources with medicinal properties are valuable for treating various oral diseases. Fluoride-mediated remineralization is the cornerstone of caries management. However, many side effects arise from its use, such as dental fluorosis. Most people could accept natural remineralizing agents compared to fluoride-based remineralizing systems. The trend is to use natural ingredients as remineralizing agents to control caries. Different naturally derived agents have been found to remineralize the demineralized enamel lesions efficiently and to prevent caries progression. The growing interest in phytotherapeutics is due to the active biological components of plant extracts and natural products. The active biological components in plants, eggshells, seashells, and other natural products play a significant role in enamel remineralization. Herbal extracts and natural products with remineralizing effects are added to dentifrice and mouthwashes to prevent caries or to enhance the remineralization of initial lesion enamel lesions.

Keywords: Aloe vera, Animal-based remineralizing agents, Biologically derived materials, Caries prevention, Cinnamon, Demineralization, Eggshells, Enamel remineralization, Fluoride, Ginger, Grape seed extract, Herbal extracts, Marine-based remineralizing agents, Minimal Invasive Dentistry, Moringa oleifera, Natural products, Non cavitated enamel lesions, Propolis, Seashells, Tea.

INTRODUCTION

Fluoride-mediated remineralization is the cornerstone of caries management. However, new remineralization strategies are developed to promote deeper remineralization of lesions, reduce the potential risks associated with high-fluoride dose, and facilitate caries control over a lifetime [1].

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Recently, the focus has been on natural products for their health benefits. Natural products are safe for use, more accepted psychologically by the patient, and already present in the food. Developing countries need biocompatible and cost-effective preventive methods due to their financial situations. It has been proposed to use natural herbal, animal, or marine products that act against the causative factors of dental caries. Most people could accept natural remineralizing agents compared to fluoride-based remineralizing systems. The growing interest in phytotherapeutics is imputable to active biological components in plants that may boost enamel remineralization and inhibit enamel demineralization [2].

Classification of Natural Enamel Remineralizing Agents

Herbal-based Remineralizing Agents:

• Grape Seed Extract

• Moringa Oleifera (MO)

• Galla Chinensis

• Aloe vera

• Tea

• Ginger

• Turmeric (*Curcuma longa*)

• Cinnamon

Marine and Animal-based Remineralizing Agents:

• Seashells

• Eggshells

Others:

• Zamzam Water

• Propolis

HERBAL-BASED ENAMEL REMINERALIZING AGENTS

Grape Seed Extract

Grape seed extract (GSE) derived from the seeds of *Vitis vinifera* (GSE) is abundant in proanthocyanidin (PA), which consists of catechin and epicatechin, gallic acid and polymeric and oligomeric procyanidins [3]. Gallic acid was found to facilitate mineral deposition on the enamel surface layer [4]. Proanthocyanidin (PA) is used as a natural antioxidant. It produces stable hydrogen and creates insoluble non-biodegradable collagen matrices [5]. Additionally, PA chelates with calcium ions increasing mineral deposition on the surface [6]. Type X collagen in the enamel matrix is involved in the mineralization of enamel [7]. Proanthocyanidin has a high affinity for collagen proline proteins producing a proline-PA complex. The collagen cross-linking characteristic of PA may be responsible for enamel remineralization. Furthermore, PA reduces collagen deterioration by transforming soluble collagen into insoluble collagen [8].

The grape seed extract promoted the remineralization of artificial enamel lesions of human primary and permanent teeth and the bovine teeth [9 - 11]. Enamel remineralization is facilitated by the chelating action of PA with calcium ions, enhancing mineral deposition and aggregation within the artificial lesions [6]. The form of grape seed extract is affecting its remineralizing potential. However, demineralized enamel specimens treated with GSE solution (12.5% w/v) for eight days reported significantly higher microhardness values compared with the control group ($P=0.03$) [12]. Spherical globular agglomerates were observed under a scanning electron microscope on the treated enamel surfaces, resembling the initiation of the remineralization process [12]. These agglomerates consisted of calcium, phosphate, carbon, and oxygen [13]. However, when the remineralizing potential of GSE was compared with bioactive glass, nano-hydroxyapatite (nHAp) (Acclaim), functionalized tricalcium phosphate (f-TCP) (Clinpro Tooth Crème), GSE recorded an increase in enamel surface microhardness but to a lesser extent than the commercially available products [14]. The remineralizing effect of PA appears to be less than that of fluoride and other products and is restricted to the superficial layer of the lesion [5]. This could be due to the high molecular weight of PA molecules in GSE that fail to penetrate the underlying layer [15]. Bleached enamel treated with GSE gel (10%) showed occlusion of enamel surface porosities and precipitates of different sizes and recorded a significant increase in the microhardness mean value as well as an increase of Ca, and Ca/P ratios (At%) values when compared to untreated bleached enamel [16].

CHAPTER 3

Natural Dentin Remineralizing Agents

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Abstract: Dentin remineralization is vital for maintaining oral health and preventing tooth decay. Natural dentin remineralizing agents have gained significant attention as a promising alternative to synthetic remineralizing agents due to their biocompatibility, low cost, and minimal adverse effects. This book chapter provides a comprehensive overview of various natural dentin remineralizing agents and their potential applications in dental therapy. The mechanisms underlying the remineralization process, the properties and sources of natural dentin remineralizing agents, and the techniques used for their extraction and formulation are discussed. Additionally, the *in vitro* and *in vivo* studies investigating the effectiveness of natural dentin remineralizing agents in restoring tooth mineralization and preventing dental caries are highlighted. Finally, the future prospects and challenges are discussed. This book chapter provides a valuable resource for dental professionals, researchers, and students interested in natural dentin remineralization and its potential applications in dentistry.

Keywords: Aloe vera, Carious dentin, Chitosan, Cranberry, Cross-linking agents, Dentin erosion, Dentin matrix stabilization, Dentin surface characteristics, Grape seed extract, Holistic dentistry, Natural Metalloproteinase inhibitors, Miswak, Moringa, Natural dentin remineralization, Natural polyphenols, Non-Carious lesion, Phytodentistry, Propolis, Tea, Theobromine.

INTRODUCTION

Demineralization is a unique disease process. Loss of mineralized tissue (carious and non-carious cervical lesions) is the most common pandemic globally [1]. When the pH is balanced, and enough calcium and phosphate ions are present in the local environment, remineralization occurs. This enables the rebuilding of apatite crystals that have partially disintegrated. To restore the natural equilibrium, demineralization or remineralization must be sped up. Early enamel lesions may remineralize, increasing their resistance to additional acid stress, especially with enhanced remineralization therapies [2]. Due to the dentin's lower

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inorganic content and higher organic content, which amplify caries development, dentin demineralization happens more quickly than enamel demineralization. Additionally, the size of the hydroxyapatite crystals in dentin is significantly smaller than that of enamel, making the dentin matrix more vulnerable to acidic attacks and increasing the complexity of dentin remineralization [3]. Several matrix metalloproteinases (MMPs), including MMPs 2, 3, 8, 9 and 20, are present in human dentin [4]. MMPs are crucial in dentin organic matrix degradation after demineralization [5]. Therefore, (MMP) inhibition can reduce the breakdown of the dentin organic part [6]. The most well-known endogenous dentine enzyme inhibitor is chlorhexidine (CHX). It inhibits the MMPs in the dentin (against MMPs 2, 8, and 9) [7]. Despite that, chlorhexidine has several adverse effects as; brown discoloration of the teeth, restorative materials, and the tongue. Taste sensation, especially for salt taste, may be altered. Rarely, parotid edema might occur and increase the occurrence of supragingival calculi [8].

Dentin remineralization is tricky as it aims to repair the dentin, improve its bond stability, and alleviate hypersensitivity. Dentin is the most considerable part of the hard tooth structure and comprises tubules. Internally, the tubules are lined by mineralized, non-collagenous intratubular dentin and encircled on the outside by intertubular dentin. After acidic attacks, dentin demineralization causes peritubular dentin breakdown, visible by enlarging the tubule lumen, whereas intertubular dentin maintains its structure. The remineralization of demineralized dentin can be accomplished using a variety of techniques. By adding phosphate and calcium ions to the demineralized dentin, the conventional ion-based method lowers the solubility of hydroxyapatite. This technique prevents the remineralization of demineralized dentin because remineralization will not occur in regions devoid of seed crystallites [9, 10]. This is another approach in which biomimetic dentin analogues of non-collagenous proteins are stabilized to provide intrafibrillar mineralization of collagen. Dentin mineralization is hypothesized to be aided by non-collagenous proteins, namely Matrix metalloproteinases (MMPs) and enzymes released by odontoblasts. They trigger Ca/P nucleation and apatite crystallization, respectively. This bottom-up remineralization technique restores the mechanical characteristics of dentin without relying on crystallites. Exogenous collagen crosslinks have been advocated to keep, reestablish, and improve tissue biochemical and biomechanical characteristics by collagen bio-alteration. These characteristics are particularly advantageous for controlling and preventing dentin caries. Additionally, they improved collagen's resistance to proteolytic deterioration. Further, the stabilized collagen can prevent demineralization and promote remineralization [11].

Remineralizing agents might be calcium and phosphate-based, herbal, fluoride-based, or a combination. Remineralizing agents can be delivered using dentifrices,

mouthwash, lozenges, or chewing gum [12]. Despite developing novel preventive strategies, fluoride is still regarded as one of the most important elements since it possesses chemical and physiological features [13]. Despite its advantages, fluoride has some limitations and drawbacks; it works best on smooth-surface caries and less well on pit and fissure caries. Fluoride has had a substantial impact on levels, although it is not an entirely effective cure. High-fluoride strategies should be pursued to avoid the potential side effects of excessive fluoride exposure. Fluoride toxicity increases with nutritional deficiencies. With increasing pressure, the anti-fluoride lobby imposes certain legal restrictions on fluoride use. Certain countries lack fluoridated products [14, 15]. The recent trend in conservative dentistry encourages using natural products rather than conventional treatment. Many organic substances have been applied as remineralizing agents. Depending on the component in question, they may influence mineral precipitation and saturation, exert an antibacterial effect, or stabilize collagen, which serves as a platform for mineral deposition [10, 16, 17].

CLASSIFICATION OF NATURAL REMINERALIZING AGENTS

I. Fruits extract

a. Grape seed (*Vitis vinifera*)

b. Cranberry (*Vaccinium macrocarpon*)

c. Citruss Fruits

II. Plants extract

a. Tea (*Camellia sinensis*)

b. Moringa olifera

c. *Aloe vera* (*Aloe barbadensis)*

d. Miswak (*Salvadora persica*)

e. Cocoa (*Theobroma cacao* L.)

f. Turmeric (*Curcuma longa* L.)

III. Natural shell

a. Grape (*Vitis vinifera*) seeds

IV. Natural sweetener

CHAPTER 4

Natural Dentin Biomodifiers

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Abstract: Nowadays, researchers are interested in using extracts from natural sources as medicines or health-promoting agents. Herbs and natural sources with medicinal properties are beneficial for treating oral diseases. Dentistry uses natural products as antimicrobial, anti-inflammatory, and sedative agents. Various physical and chemical factors, including hydrolysis and enzymatic degradation by matrix metalloproteinases (MMPs) derived from the host, degrade bonding over time. Recent biomodifications to dentin have produced a more stable and resilient adhesive contact. It has been determined that plant-derived natural cross-linkers are effective at enhancing the mechanical properties of dentin and controlling its biodegradation by inhibiting proteases. Dentin biomodification by these naturally derived cross-linking agents has remarkable effects on caries prevention and dentin remineralization, which is even more extraordinary. Natural bio-modifiers are naturally occurring substances whose potential dental applications have garnered increased attention in recent years. Compared to synthetic agents, the most appealing characteristics of biomodifiers and renewable/sustainable resources are their minimal toxicity and renewable/sustainable nature. Natural proanthocyanidins (PACs) taken from different natural sources have a high ability to cross-link with collagen. This makes the organic matrix of dentin more biostable and stronger.

Keywords: Anthocyanin, Cardol, Catechin, Chlorhexidine, Collagen, Cranberry, Cross-linker, Cysteine cathepsins, Dentin biomodifiers, Flavonoids, Genipin, Glutaraldehyde, Lycopene, MMP, Polyphenol, Proanthocyanidins, Propolis, Quercetin, Tannin, Theobromine.

INTRODUCTION

In 1955, Bounocore began the revolution of adhesive dentistry by proposing that acids could transform the enamel surface to make it more susceptible to adhesion. Thirty seconds of enamel conditioning with 85% phosphoric acid was sufficient. Later, Gwinnett and Matsui proposed that forming resin tags with phosphoric acid

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could aid the primary attachment mechanism between resin and enamel surface [1]. Until the final technique of complete etching with 37% phosphoric acid for 15 seconds was approved, more research was conducted concerning etchant concentrations, materials, and timing. Scientists did not find adhesion to enamel as challenging as adhesion to dentin, and dentin has proven to be more complex and less durable than enamel regarding adhesion.

In contrast to enamel composition, which consists of approximately 92% inorganic hydroxyapatite crystals that are regularly arranged, dentin is only 45% inorganic and has an organic matrix [2]. Dentin and pulp are regarded as a single complex component; fluid-filled channels and odontoblastic processes flow from the pulp to the dentin-enamel junction (DEJ), presenting a formidable adhesion challenge. In coronal dentin, the tubule density decreases from approximately 45,000 per mm2 at the pulp to approximately 20,000 per mm2 at the DEJ. According to measurements made by scientists [3], the tubules occupy 22%–28% of the cross-sectional area close to the dentin and only 1%–4% close to the enamel. Dentin structure and composition variations occur with depth differences from one region of a tooth to another. The organic matrix comprises roughly 90% fibrillar type I collagen and 10% non-collagenous proteins, including phosphoproteins and proteoglycans. Most organic material is found in the intertubular dentin [4]. The collagen molecules come together outside the cells to form a complex network of cross-links between and within the microfibrils, and the collagen matrix directs the deposition of minerals [5].

Mineralized dentin, except for dentinal tubules, possesses few channels allowing monomer diffusion and penetration. Additionally, the dentinal fluid's oxygen and water cannot be removed, preventing adhesive resin polymerization. In contrast, forming a residue layer during tooth preparation decreases dentin permeability [6]. Unless treated with acid or a chelating agent, the smear layer is a bilaminar structure on all restoratively or endodontically treated dentinal surfaces. The typical depth is 1 to 5 micrometers. The depth at which dentinal tubules are entered can range from a few microns to 40 m [7]. A primary dentin adhesive made of a resin based on methyl methacrylate and including phosphoric acid dimethacrylate was developed by Brudevold et al. in 1956. This adhesive was created based on a product created by Hagger in the 1940s. It was thought that bonding was facilitated by the interaction of the bifunctional molecules of this adhesive with the calcium ions in hydroxyapatite (HAp) [6]. In the 1950s, dentin bonding research progressed slowly, introducing the first commercial dentin adhesive in 1975. However, when this product was used to restore cervical carious lesions without mechanical retention, it yielded underwhelming clinical results [2]. This was followed by the introduction of the “second generation” of dentin-bonding agents in the early 1980s. They bonded to dentin through surface

hydration and interaction with calcium ions in the smear layer. In only one or two years, numerous clinical trials to restore cervical carious lesions failed. The main cause of these compounds' low effectiveness is that they bind to the smear layer rather than the dentin itself [8]. In the 1980s, the third iteration of adhesives was introduced. These modified or eliminated the smear layer to enable resin penetration into the underlying dentin, achieving better results than the second generation but not perfect retention [9]. Fusayama introduced the "total-etch" concept in Japan in the late 1980s [10]. Dentin treated with 40% phosphoric acid for 60 seconds has increased tooth-restoration bond strength [6]. Phosphoric acid for dentin etching was regarded as a harmful substance for the pulp that could cause pulpal inflammation or necrosis [11]. Etching dentin completely or partially eliminates the smear layer, and smear plugs and demineralizes peritubular dentin. The hydroxyapatite minerals are removed from the dentin surface to a depth of 5-8 m, leaving exposed collagen fibrils virtually devoid of hydroxyapatite and dentinal tubules. This lets a porous hybrid layer form [12], making it easier for hydrophilic adhesives to move within the collagen fibrils and resin tags in the tubules. Despite Fusayama's findings, many mild acidic solutions were utilized to keep etching dentin to remove or modify the smear layer of debris left over from cavity preparation. Despite the third-generation products' unsatisfactory in vitro performance, which included wide variations in bond strength values and inferior results in microleakage investigations [13], the performance *in vivo* was excellent.

THE DEVELOPMENT OF ADHESIVE SYSTEMS

Adhesive systems underwent a revolutionary change, making overcoming previous clinical obstacles possible. Existing adhesive systems enable dentists to bond to hard tooth structures without needing a prepared retentive cavity because they afford strong bonds [14]. Dental adhesive systems are made of acid, primer, and adhesive, which may be packed in bottles or applied in one, two, or three clinical steps. Van Meerbeek et al. were the first to classify adhesive systems based on their interaction with dentin into two categories in 2003 [9]: etch and rinse and self-etch. In the etch-and-rinse method, the monomers do not always get into the wet, demineralized dentin. This leaves the zones free from infiltration along the bottom of the hybrid layer, where collagen fibrils are exposed to the rinse water. In the upper half of the composite layer, acid-etched collagen fibrils are entirely encapsulated by resin, but not in the lower half [15]. Because the adhesive co-monomers demineralize and permeate the dentinal substrate, the self-etch approach does not require a separate acid-etching phase. Compared to etch-and-rinse systems, this method reduces the variation between demineralization depth and resin infiltration, resulting in a more even resin infiltration of demineralized collagen fibrils [14]. Universal adhesives have been introduced to the marketplace to simplify bonding procedures by decreasing the number of

CHAPTER 5

Natural Dentin Desensitizing Agents

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Abstract: Dentin Hypersensitivity (DH) is a common dental problem occurring worldwide affecting almost whole age ranges in the population. It is felt as a short transient pain to cold, hot, and touch stimuli and has different etiological factors. Several treatment strategies, those based on the desensitization of terminal nerve endings or occlusion of widely opened dentinal tubules, were previously proposed as effective agents in the management of DH. However, these agents contained some synthetic components that may have side effects and take longer to treat the condition. Recently, there has been a tremendous shift toward the usage of natural products in the dental field. Naturally occurring desensitizing biomaterials have shown high efficiency in treating dentin hypersensitivity. Little or no side effects, easily available, lower cost, and no need for much special equipment for production or application and preservation are some of the advantages of natural products in comparison to synthetic counterparts.

Keywords: Avian eggshell, Bee products, Calcium rich natural agents, Cow Milk, Cuttlefish bone, Cinnamon, Dentinal tubule occlusion, Dentin hypersensitivity, Essential oils, Miswak, Moringa, Natural desensitization, *Nigella sativa*, Propolis, Plant extract, Spinach, Sunflower oil, Seashell, Sesame oil, Thyme oil.

INTRODUCTION

Dentine hypersensitivity (DH) is a global clinical oral health problem in the adult population. It is defined as “pain arising from exposed dentine in response to stimuli, typically thermal, evaporative, tactile, osmotic or chemical, which cannot be ascribed to any other form of dental defect or pathology” and satisfies all the criteria to be classified as a true pain syndrome [1].

DH is also defined as an extreme response that always results in no response in a normal tooth [2]. Pashley described it as; a sharp, transient, and well-localized pain that neither arises without cause nor remains persistently following the

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removal of the stimulus [3]. Dentine is a vital tissue that contains nerves and is intimately covered by either enamel or cementum, which provide protective non-innervated coatings, and their loss results in the pain of hypersensitivity felt by the patient.

Canadian Advisory Board on Dentin Hypersensitivity (2003) defines DH as "a short, sharp pain arising from exposed dentin in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or disease" [4]. The hypersensitivity pain may be localized or generalized, related to one surface of the offending tooth or more than one [5].

The predominance and frequency of Dentin hypersensitivity (DH) have been reported in several ways throughout the years. DH occurs in an average of 57% in the age range of the adult population from 20 to 40 years of age. In the USA, more than 40 million individuals suffer from DH, 14.3% of patients attending to dental clinics, from eight to 57% of adult dentulous patients [6]. DH is more widespread among periodontally-affected patients (60 to 98%). The most affected age range is from 20 to 30, followed by the late 50s. DH involves mainly the buccal and labial cervical thirds of teeth surfaces of premolars and canines [7]. Gingival recession and the loss of cementum that occurs as a result of scaling and root planning procedures and improper brushing can lead to DH [8].

PATHOGENESIS AND MECHANISM OF DENTIN HYPERSENSITIVITY (DH)

Two successive stages have been mentioned in the previous studies that describe the development of DH; 1) lesion localization and 2) lesion initiation [9]. In the first stage, the enamel and/or cementum is lost by either attrition, erosion, abrasion, abstraction, gingival recession as a result of tooth brushing, or following periosurgery. This loss of the shielding layer leads to exposure of dentin to the external environment [10].

Many theories have been proposed to describe the mechanism of DH; most of them are closely related to the histological features of the dentin-pulpal complex [11], such as the direct nerve stimulation theory, the odontoblast-receptor theory, and the hydrodynamic theory [12].

The direct nerve stimulation theory relies on the presence of nerve endings in dentinal tubules. The theory is opposed by the fact that neural cells aren't inspected in the outer dentine either experimentally or under microscopes. It is also worth mentioning that both inter-tubular nerves and Rashkaw's plexus don't

organize themselves till teeth erupt; however, new-erupted teeth are sensitive [13].

The odontoblast-receptor theory is based on the assumption that the odontoblast is the mediator that controls the membrane potential alteration *via* a synaptic connection with the innervated pulp. Hence, the stimulation of the odontoblastic processes might occur following exposure of dentin to external stimuli. Nevertheless, this theory does not have broad scientific support in the literature [14].

The most accepted theory for the explanation of the DH mechanism is the hydrodynamic theory [15]. It is based on the assumption that the externally applied stimuli to dentine result in instant movement of the fluid inside the dentinal tubules, which in turn stimulate the mechano-receptors causing pain. Airflow, thermal stimuli, osmotic stimuli (acids, salts, and sugar), and touching with a dental instrument all these factors can result in changes in dentinal fluid movement, triggers pain receptors, and hence elect pain of DH. The number of patent dentinal tubules and their diameter are distinguishing features of the hypersensitive tooth. It is worth mentioning hypersensitive teeth have an increased number of opened tubules, almost eight times per unit area, in comparison with normal. Besides, the dentinal tubules of teeth affected by DH have wider diameters than those of normal teeth, as confirmed by scanning electron microscopic images [16]. The hypersensitive dentinal tissue can be distinguished from the non-sensitive dentinal tissue in that more advent and patent tubules are inspected under SEM [17]. Common precipitating factors for DH are loss of external coverage as the loss of enamel or cementum as a result of gingival recession [18]. The exact mechanism of dentin hypersensitivity is still under research [19].

Diagnosis of Dentin Hypersensitivity (DH)

DH diagnosis usually relies on the patient's self-complaint of pain or discomfort [20]. Hence differential diagnosis is mandatory to exclude other similar diseases or conditions having the same clinical feature of bare and sensitive dentin, such as cracked and chipped teeth, fractured cusps, caries, poorly adapted dental restorations, periodontitis, endodontic diseases such as pulpitis, and post-bleaching sensitivity [21]. To assume an accurate diagnosis, a full clinical and radiographic examination, and a complete dental history must be fulfilled [22]. The disease is always diagnosed by applying air (from a triple air syringe) and tactile stimuli (by dental exploration probe) to the exposed dentin of the offending tooth. The degree and severity of DH pain can be counted according to the Verbal Rating Scale (VRS) (*i.e.*, slight, moderate, and severe) or using a visual analog

CHAPTER 6

Natural Dental Bleaching Agents

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Abstract: Nowadays, bleaching is one of the most common procedures in aesthetic dentistry. When comparing bleaching to other treatment options for vital teeth whitening such as crowns or ceramic laminates, it proved to be more conservative. Bleaching is not only a well-established technique but also provides effectiveness and patient satisfaction. Carbamide peroxide and hydrogen peroxide are the active components used for bleaching. Although bleaching is a well-tolerated method, some patients still report sensitivity during and after bleaching. Hydrogen peroxide is considered the main agent responsible for this hypersensitivity. The bleaching effect is the result of the oxidation reaction of the tooth pigments by means of the hydrogen peroxide molecules. Serious damage to the pulp tissue can be the result of the reaction's by-products reaching the pulp. The deleterious effect of the bleaching agents is not only on the pulp but also on the gingival tissues and bone, where bone inflammation and resorption have been reported. Therefore, efforts have been made to obtain effective tooth bleaching with less or no harmful effects on enamel, pulp, and oral mucosa and with no contraindications. Natural alternatives to peroxide bleaching have been mentioned in the literature. These alternatives can produce an oxidative reaction and stain removal effects, without deleterious outcomes. Natural products give us some certainty about non-cytotoxic biological behavior, resulting in little or no harmful effects. Also, the organic acids present in raw fruits have demonstrated the ability to maintain or improve the color of the teeth. Therefore, the development of new tooth-bleaching agents based on natural products with comparable aesthetic results and minor side effects would be beneficial.

Keywords: Activated Charcoal, Bromelain, Caffeic acid, Caproic acid, Carbamide peroxide, Citric acid, Dairy products, Ellagic acid, Glycolic acid, Hydrogen peroxide, Lactic acid, Limonene, Malic acid, Miswak, Natural bleaching agents, Natural bleaching salts, Oil pulling, Papain enzyme, Plant-based bleaching agents, Salvadorine, Silica, Tooth bleaching, Tooth whitening.

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INTRODUCTION

Tooth surface discoloration not only affects the esthetic appearance of the patients, but it can also negatively affect the patients' psychology, so it is considered one of the main reasons to seek dental care. Understanding the etiology of tooth discoloration is very important for making the proper treatment plan. The tooth discoloration can be either internal or external discoloration [1]. When studying the metabolism and physiology of teeth, there are a lot of reasons which cause discoloration. Dyes and stains can percolate into the porous structure of the enamel. Common ingredients like tea, coffee, and antibiotics like tetracycline and food dyes can percolate into the porous structure of the teeth, causing teeth staining that remains. Smoking is another factor for teeth discoloration. Additionally, teeth become discolored with age due to stain accumulation and enamel wear that exposes the yellow-colored dentin. Another cause of teeth discoloration is calculus accumulation [2]. According to the Food and Drug Administration (FDA), the two terms tooth "bleaching" and tooth "whitening" are not the same. The whitening process that will whiten the teeth beyond their natural color is known as tooth "bleaching". The active ingredient used for this process is mainly peroxide, which acts by releasing oxygen molecules. These molecules will break the stain pigmentation after getting inside the microfractures present within the enamel. While the process of restoring the tooth's natural color, through stain removal is known as tooth "whitening" [3, 4].

Current commercial bleaching products contain oxidizing agents such as hydrogen peroxide or peroxide-releasing agents like carbamide peroxide or sodium perborate [5]. Because of being safe and easily applied, these substances became increasingly popular [6]. Upon bleaching, the hydrogen peroxide and other reactive oxygen species (ROS) act on the staining molecules releasing them. This leads to a change in the optical properties of dental structures as well as that of restorative materials. This change will in turn result in the bleaching effect [7]. Unfortunately, these highly active ROS can reach the pulp chamber through diffusion across the mineralized dental structures [8] depending on concentration [9]. Upon reaching the pulp chamber they can cause oxidative damage to cellular proteins, lipids, and nucleic acids [10, 11]. This leads to a negative effect on the organic matrix of the dental hard tissues and/or inflammation of the dental pulp [4], genotoxicity, carcinogenesis, and even cell apoptosis and necrosis [12 - 14]. The local effects are dependent on the used technique as well as the products' concentration. Studies also showed that when using 35% hydrogen peroxide for bleaching cellular changes in enzymes in the dental tissues will take place [15]. Increasing the number of applications and the concentration of the bleaching material would increase the cytotoxic effects severity. Moreover, applying the

bleaching agents daily, even those used at home can lead to increased pulpal cell damage [6].

"Over-the-counter products" including whitening strips, toothpaste, and mouthwashes are other techniques that can be used at home [16, 17]. Today, oral hygiene products and mouthwashes are available that control cariogenic biofilms chemically and remineralize teeth as well. As patients' interest in dental aesthetics has increased in recent years, mouthwashes that contain hydrogen peroxide (HP) have become more popular [18]. It is not only the enamel but also the soft tissues that are adversely affected by the chemical ingredients in whitening products. Mucosal irritation, ulceration, and circumoral dermatitis may result from these chemicals. Due to their chemical-free nature and lack of harmful side effects, herbal products have become increasingly popular. They possess anti-inflammatory, antimicrobial, astringent, antidiabetic, antifungal, analgesic, and antiseptic properties, which make them effective [19]. This has led to the introduction of numerous herbal products to the market, including whitening toothpaste. Papaya (papain enzyme), menthol, miswak, clove, salt, and citrus fruits are among the herbal whitening ingredients in toothpaste [20].

Natural products are used in a variety of contexts in dentistry, including oral hygiene products (dentifrices, mouthwashes, restorative materials, endodontic and periodontal dressings), caries prevention [20], and xerostomia [21, 22]. Herbal medicines are becoming increasingly useful in the dental field [23]. As an alternative to the harsh chemicals available as teeth-whitening agents, natural organic ingredients found in fruits such as lemons, strawberries, oranges, papaya, and activated charcoal can help whiten teeth more safely and gently [24].

As a result, developing new natural-based teeth whitening methods with equivalent aesthetic outcomes and fewer side effects would be extremely beneficial. Dietary habits high in raw fruits and vegetables and high in organic acids appear to preserve and improve tooth color [24, 25], although the mechanism is less well understood.

PLANT-BASED NATURAL BLEACHING AGENTS

Coconut (*Cocos nucifera*) Oil

The name coconut comes from the Spanish and Portuguese word coco, which means "monkey face". In Sanskrit, the coconut palm is known as Kalpa Vriksha, which means "tree that provides life necessities," because almost every part of the tree is useful in one way or another [23]. Oil pulling has been used for centuries as an Indian remedy to treat oral malodor, gingival bleeding, and dry mouth. It is also believed that it can strengthen the teeth and prevent decay. Olive, sunflower,

CHAPTER 7

Natural Dental Antioxidants

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Abstract: Discoloration of teeth is a common concern among patients seeking cosmetic treatment. The color of teeth can be affected by various factors, both internal and external, such as ingestion of chemicals or consumption of foods that can cause staining. Currently, there are numerous products available in the market that claim to remove stains and whiten teeth. These options include professional prophylaxis, bleaching gels applied to vital teeth for home use, or supervised application in a dental office. Bleaching gels typically contain varying concentrations of carbamide or hydrogen peroxide and are applied using different methods, resulting in different activation mechanisms that promote tooth bleaching through oxi-reduction reactions. Unfortunately, bleaching agents have an adverse effect on bonding to enamel. This is because of the free radicals generated by the breakdown of hydrogen peroxide-containing bleaching agents. The free radicals hinder the resin infiltration in the inter-prismatic spaces, inhibit resin polymerization , and restrict resin tag creation. These free radicals are eliminated from the body within a span of 24 hours to 3 weeks, and the bond strength to enamel is restored. So bonding should be postponed for 1-3 weeks so that the bond strength is restored, but this waiting period is not always clinically possible. The use of antioxidants could be a possible solution to immediately restore the reduced bond strength. Antioxidants could be either synthetic or natural. Although synthetic antioxidants proved to have the ability to restore bond strength, they have many adverse effects. Natural antioxidants could be a good alternative to synthetic ones with no side effects.

Keywords: Antioxidants, Adhesive interface, Bleaching, Catechins, Enamel bond strength, Epicatechin, External antioxidants, Flavonoids, Free radicals, Hydrogen peroxide, Hydroxyl groups, Microshear bond strength, Natural agents, Natural antioxidants, Phenolic compounds, Proanthocyanidins, Reactive oxygen species, Salivary antioxidants, Sodium ascorbate, Synthetic antioxidants, Tocopherol.

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INTRODUCTION

The desire for tooth whitening has risen due to people's growing concern for enhancing the aesthetic of their smile, and dentists are opting for less invasive, conservative dental treatments. Tooth bleaching can be carried out using various bleaching agents, concentrations, and light stimulation methods [1]. It is categorized as either vital or non-vital tooth bleaching. Vital tooth-bleaching procedures take place at home, in a clinic, or with over-the-counter products [2]. While being comparatively easy, yielding great outcomes, and preserving the dental structure, it can negatively affect enamel. Furthermore, bleaching diminishes the adhesive power of resin composite on formerly whitened enamel [3 - 5].

EFFECT OF BLEACHING ON ENAMEL BOND STRENGTH

When a bleaching agent that contains hydrogen peroxide contacts teeth, it breaks down into free radicals. Among these radicals, hydroxyl radicals, perhydroxyl nascent oxygen, and superoxide anions exhibit the strongest oxidizing potential [6]. They are highly reactive against chromophores, which are organic compounds that cause tooth discoloration. The intrinsic stains are targeted by free radicals through an oxy-reduction reaction, which breaks down the large pigment molecules into smaller ones. These smaller molecules stay in the teeth but cannot absorb light anymore [7 - 9].

The adhesive power linking resin composite and enamel surface that has been immediately bleached may be reduced by 25-60%, contingent upon the potency of the bleaching substance [10 - 12]. This reduction is because of the remaining free radicals that are produced during the breakdown of hydrogen peroxide, as well as modifications in the composition and microstructure of enamel [13 - 17]. Images of scanning electron microscope (SEM) of the enamel composite interfaces of unbleached enamel, display a uniform, gap-free adhesive junction (Fig. **1**). However, Fig. (**2**) shows the enamel composite interfaces of bleached enamel without the use of any antioxidant, which exhibits a broad interfacial gap at the adhesive interface [18].

It is believed that oxygen present in the hydrogen peroxide is taken by tooth structure. Subsequently, it is discharged through surface diffusion and gathers within the enamel configuration [13 - 17]. This remaining oxygen hinders the resin infiltration in the inter-prismatic spaces, inhibits resin polymerization [10 - 12], and restricts resin tag creation [7]. Furthermore, changes in pH are caused by the oxygen-free radicals that are released due to the breakdown of hydrogen peroxide into oxygen and water [13, 14]. Moreover, released oxygen may be confined in the adhesive during light activation. Consequently, the polymerization

process may not be fully completed, and air pockets resembling bubbles could appear at the interface. This causes bond strength to be reduced. Additionally, this reduction may be temporary following bleaching because of changes in enamel morphology and composition [10 - 12]. These changes can also affect the enamel micro-hardness, which in turn affects its bonding ability. The oxidative impact of peroxide radicals and urea present in carbamide peroxide bleaching agents may also influence the organic structure of the enamel subsurface, resulting in alterations in its mechanical properties [8, 19]. All of these changes impact the organic phase of the enamel surface and could potentially spread to the subsurface. They may be a result of natural permeability canals within the enamel structure, such as prism sheaths, intercrystalline matrix, striae of Retzius, enamel lamellae, or pores that result from the demineralization associated with certain bleaching agents that have low pH. Hydrogen peroxide's low molecular weight permits it to penetrate deeply into the enamel, potentially reaching dentin and even pulp. The bleaching process can lead to demineralization up to 50 millimeters beneath the surface of the enamel.

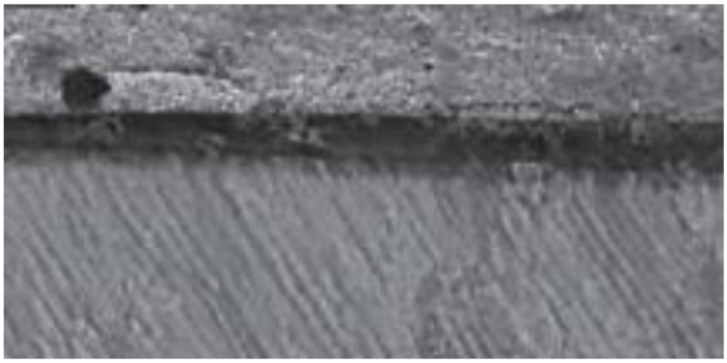

Fig. (1). SEM images at 2000 X magnification of enamel composite interfaces of unbleached enamel show a uniform gap-free adhesive [18].

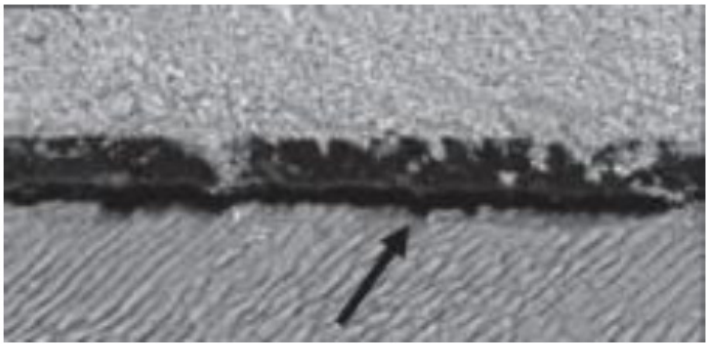

Fig. (2). SEM images at 2000 X magnification of enamel composite interfaces without the application of any antioxidant show a broad interfacial gap [18].

CHAPTER 8

Natural Vital Dental Pulp Therapy

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Abstract: Curiosity in pharmaceutical greenery has blossomed due to the expanded productiveness of incoming herbal extract medicine and the rising concern in natural materials to avoid the undesirable effects of traditional drugs. This comes in the same line with the need to keep up pulp liveliness and function of the normal pulp tissue, which is essential for reparative dentin formation. In the previous decade, fully grown adult teeth with pulp exposure had fewer favorable results, and endodontic treatment choice has succeeded over other therapies. Now, eradicating microorganisms from dentin pulp complex and promoting renewal has become the focus of attention. Different materials used in vital pulp therapy procedures help dentin-pulp complex protection; nevertheless, these materials have different side effects, leading to failure of the procedure after a period of time. This article throws light on natural products used in vital pulp therapy procedures that assist in achieving security across pulp-dentin organs with fewer side effects on pulp health over a period of time.

Keywords: Ankaferd blood stopper, Growth factor, *Nigella sativa*, Pulp regeneration, Propolis, Turmeric.

INTRODUCTION

The dental pulp is a connective tissue with many tasks, such as initiation, formation, protection, nutrition, and reparative activities. However, it is circumfluent by mineralized tissue, which gives it relatively low compliance against destruction caused by dental caries. This leads to the recurrent elimination of pulp tissue through endodontic procedures. Removal of pulpal tissue regularly causes weakness of tooth structure and, finally, worsening in the human's grade of mastication. Now, it is obvious that numerous root canal therapies or the removal of teeth could be bypassed if the vitality of the pulp is properly maintained [1].

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Maha Ahmed Niazy, Hesham El-Enshasy & Shimaa Mahmoud Ameen (Eds.)

Vital pulp therapy (VPT) is a conservative and biological therapeutic option to maintain the liveliness and job of normal pulp tissue in vital adult teeth. After pulp exposure, our target is to foster the recovery of pulp tissue and allow reparative dentin formation to maintain pulp health and vitality. Vital pulp therapy steps include detaching localised irritants and applying covering material in contact or without contact with pulpal tissue. Tight-sealed restoration is mandatory and used after that treatment to decrease bacteria leakage from the surrounding media [2]. The pulp capping procedure is one of the majorities of famous and little destructive treatments in vital pulp treatment that utilizes different types of substances to achieve clinical prosperity, such as zinc oxide eugenol, calcium hydroxide, and mineral trioxide aggregate.

Zinc oxide eugenol was used as a pulp therapy material because it has sedative and palliative effects on pulp. Nevertheless, after a time interval, it was observed that the eugenol release has a cytotoxic effect on pulp tissue and leads to a spacious amount of interfacial leakage, causing low effectiveness [3].

Calcium hydroxide ($Ca(OH)_2$) was reviewed as the basic pulp therapy material. It has an alkaline pH of 12.5, which, unfortunately, leads to the death of pulp tissue when it comes in direct contact with it. Certain $Ca(OH)_2$ concentrations lead to the death of fibroblast cells, leading to pulp tissue damage. Moreover, $Ca(OH)_2$ after a long time of use can cause physical variation; the density of the formed tertiary dentine is not adequate because of discontinuity in the dentin layer, which leads to a necrotic part called “tunnel defect” [4].

On the other hand, mineral trioxide aggregate (MTA) in some objective evaluations has been shown to have near effects to calcium hydroxide as a pulp therapeutic agent; however, part of other research with an objective follow-up time of 24 months proved MTA to have preferable clinical success than calcium hydroxide [5]. Nevertheless, MTA has disadvantages like handling characteristic difficulty, prolonged setting time, being expensive, and the ability to discolor tooth structure [6].

All these problems require dentists to explore replacement materials, depending on natural herbal-based ingredients. Attentiveness to pharmaceutical herbs has blossomed due to the rise in the effectiveness of incoming herbal extract material and the rising concern about natural stuff due to the reviews about the damage caused by traditional medicine [7].

NATURAL MATERIALS FOR VITAL PULP THERAPY

• Propolis

• Turmeric

• Ankaferd Blood Stopper (ABS)

• *Nigella sativa* oil (NS)

• Growth Factors

✓ Bone Morphogenic Protein (BMP)

✓ Transforming growth factor (TGF)

✓ Platelet-derived growth factor (PDGF-BB)

• Platelet-rich fibrin (PRF)

• Lyophilized freeze-dried platelet

• Platelet Rich Plasma

• Enamel matrix derivative (EMD)

Propolis

Propolis is a natural product from bees, composed of balsam resin, beeswax, essential oils, and pollen from other organic products. It has been shown to play a role in vital pulp therapy and the repairing procedure because it has anti-bacterial, anti-fungal, anti-virus, anti-tumour, anti-oxidation, and immunomodulatory properties [8]. The toxicity effect of Propolis on fibroblast cells has been reported to be low and has the potency to prevent apoptosis and enhance fibroblast cell proliferation [9]. Adding to that, Propolis could be used as a natural substitution for vital pulp therapy because it can reduce pulp inflammation naked to cariogenic product [10]. The prevention of nuclear factor kappa-light- chain- enhancer of activated B cells (NF-kB) by the major element of Propolis leads to a lessening in the expression of proinflammatory cytokine genes, such as IL-1, IL-6, IL-8, and TNF-α, which lead to the down-regulation of TLR-2 in pulp tissues [11, 12]. Caffeic acid phenethyl ester (CAPE) is one of the energetic elements of Propolis that has been inspected. The role of this element has been detected to inhibit cancer, inflammation, and immunomodulation [13] successfully. The generation of collagen in the pulp tissue is encouraged by CAPE, and the degree of pulp inflammation and degeneration decreases [14].

CHAPTER 9

Recent Development in Oral Hygiene Products: From Product Development to Market

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Abstract: Oral care or oral hygiene products become one of the main components of our daily healthcare products with increased market growth. This is driven by the increased awareness of the importance of a healthy lifestyle to prevent many diseases. For years, many products in this market have been formulated based on pure chemicals, categorized under the toxic category, which could have a negative impact on human health as daily/regularly used products. With the increased awareness of the importance of using natural alternative components as safe and non-toxic ingredients, growing demands have been created for natural dental care products. In addition, with extensive research on human microbiomes and their essential role in maintaining a healthy life and enriching this type of healthy microbes as the first line in fighting against disease, microbiome-friendly products and probiotics-enriched products have been recently introduced to the market. Therefore, the need for innovative and safe products is in high demand nowadays to fill a specific market gap in new niche areas. This chapter addresses the recent developments in the oral hygiene products market and products with comprehensive updates about the growth of the development of natural ingredients-based products in this business sector.

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Keywords: Herbal mouth care, Mouthwash, Mouth spray, Probiotics, Oral care market, Toothpaste, Whitening.

INTRODUCTION

Oral healthcare oral hygiene products become one of the main components of the health and wellness industries nowadays. This includes a wide range of products, pure physical products with or without the addition of some chemical compounds, such as toothbrushes, tooth floss, denture fixatives, or chemical substances either pure chemicals or with the addition of natural products such as toothpastes, mouthwashes, and mouth sprays. These products play a crucial role in oral cavity components, which include soft and hard tissues. The oral cavity includes organs of different sensitivity to chemicals, such as gums, tongues, teeth, and bones. Therefore, the design of any oral hygiene product should consider three main components to ensure the acceptability of products to the market. First, to ensure the product is safe neither toxic nor carcinogenic and suitable for the different types of tissues of the oral cavity; and secondly, to ensure that it will have the functional ingredients that help perform the claimed function, such as biofilm removal, whitening, and antimicrobial properties. Third, quality is important to meet customer satisfaction and acceptability of products such as taste, smell, texture, *etc*.

ORAL CARE MARKET: PRODUCT TYPES AND MARKET GROWTH

Oral care/hygiene products are generally used to keep the mouth clean, have a pleasant odor, to remain free of diseases and to prevent dental disorders such as gingivitis, tooth decay, and periodontitis (gingival diseases). However, the oral hygiene market can be classified into two main components. First, the products with regular customers to keep the oral cavity clean, and fresh looking, such as those found on the shelf in drug stores and regular supermarkets (toothbrushes, toothpaste, mouthwash, mouth spray, *etc*.), and secondly, the products used in the treatment and dental service by a dentist such as cavity filling, teeth scaling, special antimicrobial rinsing agents, *etc*. The international market of oral care products reached USD 22.3 billion in 2022 and is expected to reach USD 34.1 billion by 2033, driven by a global market compound annual growth rate (CAGR) of about 3.9% (even the CAGR of this market was 3.5% during the period 2015-2022) [1].

In 2022, toothpaste sales contributed to the most significant portion of oral care products, with a market share of 36.3%. The market value of toothpaste is expected to reach USD 8.5 billion by 2023. The main sales channels of oral care include consumer stores, retail stores, online distribution, and dental treatment

centers. However, hypermarkets and supermarkets are considered the primary sales channel, with a market value of USD 6.9 billion (about 30.8% of the market value).

Regarding geographic distribution, the U.S. market is considered the leading market, accounting for about 21.9% of the world's oral care market in 2023. In another part of the world, mid-low-class countries such as India and many Southeast Asian countries, the market is driven by economic growth and the increased awareness of the importance of oral health in the human quality of life. Oral healthcare products become lifestyle products in different parts of the world.

ORAL HEALTH CARE PRODUCT

The customers' mouth healthcare products can be classified into two main categories based on the treatment method, either mechanical or chemical treatment (Fig. **1**). The mechanical treatment includes a toothbrush (synthetic or natural), a chewable toothbrush, and teeth floss. The chemical oral health care products include (toothpaste, mouthwash, mouth spray, and gum gel. However, some dental products for mechanical treatment of teeth for stain removal or cleaning include some chemical ingredients, either synthetic or natural, to increase the product's effectiveness or to provide a pleasant aroma and refreshment feeling. A combination of both types of products is also common in our daily uses, such as tooth brushing, which involves (toothbrush and toothpaste).

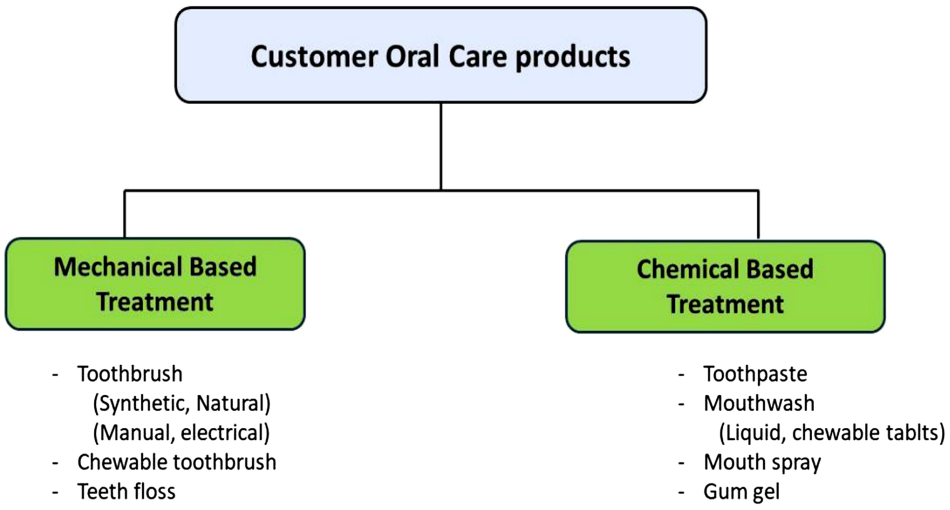

Fig. (1). Classification of customer oral care products based on the treatment method.

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