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Use Of Essential Oils In Dentistry Against Dental Caries -A Review

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Abstract

Dental caries pose a significant public health problem across the world affecting school children and a large majority of adults as they contribute to a massive loss of natural teeth worldwide. The cause of dental caries is the bacterial biofilm that shelters tooth surface and later causes tooth loss, therefore biomaterials such as titanium dental implants are used to replace a missing tooth. Titanium implant is inserted into the jawbone to replace the missing tooth; however, it can also fail due to bacteria that shelters their surface. Essential oils are promising natural products and have been used for hundreds of years as natural medicines to fight a wide range of pathogens, including bacteria, fungi, and viruses. As a results there has been an increased interest in the use of essential oils because of their antifungal, antibacterial, and antioxidant properties. Antibiotic resistance is a major health problem as microorganisms can survive and increase in the presence of antibiotics however the chief benefit of natural products such as essential oils is that they do not increase antibiotic resistance compared to the long-term use of synthetic antibiotics. When bacteria are treated with essential oils, these oils degrade the cell membrane which is detrimental to the cytoplasmic membrane. Therefore, essential oils inhibit the growth of pathogens by targeting the membrane and cytoplasm and, in some cases, they totally alter the structure of the bacterial cell. Essential oils have shown great potential in the biomedicine field and therefore their use in dentistry can be beneficial.

Keywords: Antibiotic resistance, essential oils, biomaterials, dental caries

Introduction

Various articles explored the antimicrobial activity of natural products, such as essential oils, against a varied range of oral pathogens that are particularly found in food. The chief benefit of indigenous products is that they do not increase antimicrobial resistance compared to the long-term use of ersatz antibiotics (Högberg et al., 2010; Fournomiti et al., 2015). According to Kavanaugh and Ribbeck (2012), plant-derived essential oils have been used for hundreds of years as natural medicines to contest a wide range of pathogens, including bacteria, fungi, and viruses. Furthermore, in recent years there has been an increased interest in the use of essential oils because of their antifungal, antibacterial, and antioxidant properties (Ntondini, 2021; Pandey et al., 2017). Moreover, apart from their antibacterial properties, essential oils have been described to show antiviral, antimycotic, antioxygenic, antiparasitic, and insecticidal properties (Predoi et al., 2018).

Medicinal plants that contain essential oils have been used in developing countries as complementary treatments for health problems (Bernardes et al., 2010; Ntondini et al., 2021). There is thus an escalating interest in what is termed 'green consumerism' that has led to the use of plant-derived natural products. These products are used as preservatives and essential oils and their compounds are acknowledged to possess inherent antimicrobial properties (Dagli et al., 2015; Prakash et al., 2018). Essential oils are also used in different industries. For instance, they are used in perfumes and lotions, in foodstuff as preservatives and for additives, and in pharmaceutical products for therapeutic action (Prakash et al., 2018). There has thus been an increasing inclination towards the use of organic and natural products among health conscious consumers. For instance, the global essential oils market was reported to be 226.8 kilotons in 2018, and it is expected to increase to a compound annual growth rate (GAGR) of 8.6% from 2019 to 2025 (Irshad et al., 2020). The rise in the demand for essential oils globally is the result of its antimicrobial and health benefits (Table 1). Unlike synthetic antibiotics which lose their potency against diseases causing organisms, it is not yet reported that bacterial have developed resistance against essential oils. Since essential oils have been used for centuries and still maintain their potency against microorganisms, it is important to research their application in dentistry as antibacterial agents. Due to the nature of the mouth, it breeds many harmful organisms which cause dental problems (tooth loss, tooth decay).

Table 1. Health benefits of essential oils

Essential oil	Composition	Pathogens	Applications	References
Eucalyptus globulus (Eucalyptus oil)	1,8-cineole followed by cryptone, α-pinene, p-cymene, α-terpineol, trans-pinocarveol, phellandral, cuminal, globulol, limonene, aromadendrene, spathulenol and terpinene-4-ol	Escherichia coli, Staphylococcus aureus	Anti-cariogenic agent Antiseptic for the treatment of measles, scarlet fever, influenza and typhoid fever	(Irshad et al., 2020; Gherasim et al., 2021).
Mentha piperita (peppermint oil	Menthol (major compound), menthyl acetate and menthofuran	Staphylococci, Enterococcus fecalis, Staphylococcus aureus, Candida albicans and Escherichia coli	Antimicrobial activity - Utilised in oral hygiene products, for example in mouth rinses. Extremely powerful for combating oral pathogens and killing bacteria that cause dental caries and gingivitis. Is also used to freshen your breath.	(Irshad et al., 2020).

			Also, for the treatment of Exhaustion, nausea, fever and asthma	
Melaleuca alternifolia (Tea Tree Oil)	terpinen-4-ol, γ-terpinene, p-cymene, α-terpinene, 1,8-cineole, α-terpineol and α-pinene	C.albicans, Staphylococcus	Oral candidiasis - Mainly used in prophylactic oral hygiene products Antifungal activity. E.g. Melaleuca alternifolia consists of antimycotic activity, terpinen-4-ol being its greatest effective component used to treat cold sores. Also, antibacterial and antifungal for cuts and flu	(Warnke et al., 2009; Irshad et al., 2020).
Syzygium aromaticum (Clove oil)	phenylpropanoids eugenol, eugenyl acetate, carvacrol, thymol, cinnamaldehyde, β-caryophyllene and 2-heptanone	C.albicans, Staphylococcus	Natural ability to control the develop-ment of bacteria and can help fight mouth and throat infections	(Warnke et al., 2009).
Lavendula officinalis (lavender oil)	50% linalyl and 35% linalool of linalyl acetate (3, 7-dimethyl-1, 6 octadien-3yl acetate), linalool (3, 7-dimethylocta-1, 6-dien-3-ol), lavandulol, 1, 8-cineole, lavandulyl acetate	Enterococcus fecalis, Staphylococcus aureus, Candida albicans as well as Escherichia coli	Used as an anxiolytic in dental clinics. Reduces pain of needle insertion. Treating painful inflammation of the skin. It is also used in wound healing processes as this oil promotes healing of the skin tissue	(Dagli, 2015; De Rapper et al., 2016).
Leptospermum scoparium (Manuka oil)	caryophyllene, geranoil, pinene, humulene, linaloool and leptospermone	Enterococcus fecalis, Staphylococcus aureus, Candida albicans and Escherichia coli	This oil helps the scars and after marks on the skin to fade away by promoting new cell growth in the affected parts of the body and protecting wounds from developing infection	(Warnke et al., 2009; (Patil, 2019)

The growing antimicrobial resistance to antibiotics is continuing to be a global crisis that has driven research into finding new natural alternatives with far-reaching action (Nazzaro et al., 2013; Alcock et al., 2020). One of the main causes associated with antibacterial drug resistance is the misuse and overconsumption of these drugs that are found in human medicine and in agricultural products (Chokshi et al., 2019). The food chain is also considered a main route of transmission of antibiotic resistant bacteria among animal and human populations. Because the antibiotics that are used in agriculture often have the same or similar compounds used clinically for the treatment of various infections, this overuse contributes to drug resistance (Zaman et al., 2017). The World Health Organization (2016) states that antibiotics are largely used to combat bacteria that can cause illnesses, diseases and infections, but antibiotic resistance continues to be a public health challenge. In the earlier years of antibiotic use, they had a major impact on extended human health as many diseases that had once caused death were effectively treated with antibiotics. However, some bacteria such as Staphylococcus aureus have become resistant to commonly used methicillin, amoxicillin and metronidazole antibiotics, and Escherichia coli have become resistant to ciprofloxacin (World Health Organization, 2016; Moradigaravand et al., 2018).

Antibiotics can commonly get rid of most bacteria in a colony, but a different strain of bacteria that has mutated genetically can result in resistance (Zaman et al., 2017). Antibiotics also fail to inhibit bacterial growth because bacteria can change or limit the number of openings in cell wall. Antibiotic drug molecules normally gain access to the cell by diffusion through the porins found in the outer membrane of Gram-positive bacteria, which means that a reduction in the number of porin channels leads to a decrease in the entry of antibiotics into the cell (Nazzaro et al., 2013; Kapoor et al., 2017). The cytoplasmic membrane of bacteria has pumps that take antibiotics out of the cell, and these 'pumps' are known as efflux mechanism pumps. For example, Tetracyclines, Macrolides, Lincosamides, Streptogramins, Oxazolidinones, Phenicols, Cationic peptides, Lipopeptides, Quinolones, Pyrimidines, Rifamycins and the Sulfonamides groups of antibiotics are pumped out in this manner (Zaman et al., 2017). The pumps function at the same speed as the speed at which antibiotics gain access to the cells and they thus pump the antibiotic out before it reaches the target. The outer membrane of a Gram positive bacterium thus keeps the antibiotic from gaining entrance into the cell (Nazzaro et al., 2013; Kapoor et al., 2017).

It is for this reason that microorganisms are becoming more antibiotic resistant as they can survive and increase in the presence of antibiotics. They tend to prevent the antimicrobial from meeting its target by limiting its ability to enter the cell. Essential oils, on the other hand, have shown great potential in the field of biomedicine as they have the ability to efficiently destroy several fungal and viral pathogens. Essential oils inhibit the growth of pathogens by targeting the membrane and cytoplasm and, in some cases, they totally alter the structure of the cells (Warnke et al., 2009; Chouhan et al., 2017).

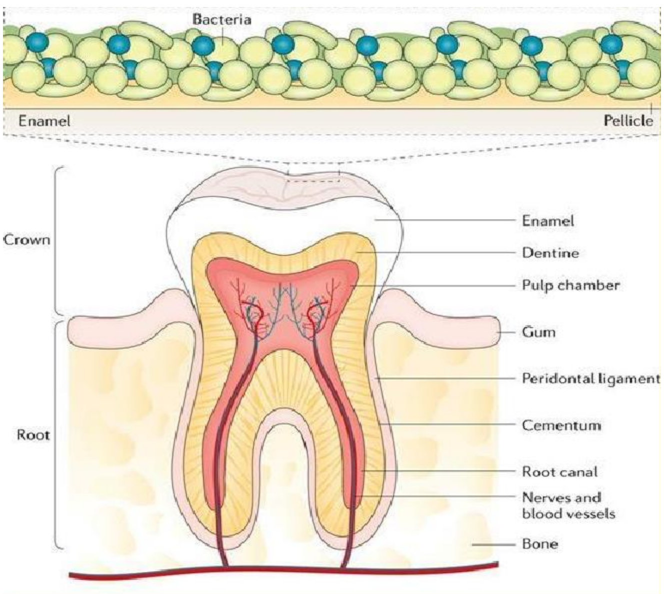
In the dentistry field, essential oils have mainly been utilised to provide calmness and relaxation to patients and to manage emotional distress. Aromatherapy is also regarded as useful in treating oral ulcers and toothache (Baig et al., 2017). However, it has been argued that more intensive research needs to be conducted on the broader usage of essential oils in dentistry (Ferreira et al., 2021) which must be the focus of future studies.

Dental Caries

The term dental caries is defined as the destruction of vulnerable hard dental tissue by acidic by-products that are released from the bacterial fermentation of dietary carbohydrates. The main trigger of dental caries is the biofilm of the bacteria that shelters the surface of the tooth (Selwitz et al., 2007; Pitts et al., 2017). This biofilm development is generally sugar driven and results in the phasic demineralisation and remineralisation of hard dental tissue (Pitts et al., 2017). Dental caries occurs primarily upon the tooth crown but later also affect the root surfaces of teeth if not treated.

Figure 1 shows the anatomy of a normal tooth. Bacteria usually colonise the hard tissue of a tooth, which is the enamel. The hard tissue of the tooth is comprised of enamel, dentine, and cementum. Enamel is a hard material containing mostly hydroxyapatite and protects the dentine on the crown of the tooth. Cementum is a bone-matrix-like substance that is composed of minerals and collagen and encompasses the root of the tooth. The dental pulp shapes the central part and is comprised of connective tissue, blood vessels, and nerves. Teeth are enclosed by a salivary pellicle layer that contains proteins and glycoproteins that facilitate attaching of the oral microbiota to the teeth. This structure (oral microbiota) is called the dental biofilm, also known as dental plaque. The biofilm closes off the surface enamel from the saliva and oral cavity and creates a protected microenvironment at the surface of the tooth. Gingiva, which is commonly known as the gum, surrounds the teeth (Pitts et al., 2017). Saliva, which is a specialised fluid that is secreted in the mouth throughout the day, maintains the integrity of the teeth. Saliva in the mouth is vital as it combats oral pathogens by buffering the oral environment at a neutral pH, which is ideal for the development and metabolism of most of the oral pathogens, while also supplying proteins and glycoproteins as nutrients. Biofilm development that causes dental caries normally occurs at night when there is no movement of the saliva that protects the mouth and teeth against bacteria (Petersen and Ogawa, 2016; Pitts et al., 2017).

Figure 1. Composition of a tooth (Pitts et al., 2017).



Dental cavities pose a substantial public health challenge across the world as these illnesses impact approximately 60–90% of young children and the greater number of adults as they contribute to a massive loss of natural teeth globally (Petersen and Ogawa, 2016; WHO, 2016).

Dental Implants

A dental implant is normally a small screw finished with a biometal such as titanium which is biocompatible with the tissue surrounding the tooth. It is not harmful or toxic to living tissue (Coffigniez et al., 2021). The implant is inserted into the jawbone to replace the missing tooth (Khammissa et al., 2012). Titanium and its alloys are the prime biometals for producing such biomedical devices for dental applications due to their distinctive combination of physical, chemical, and biological properties. The preference for Ti-based alloys for biomedical applications above other biometals is due to the development of a very thin adherent protective titanium that is a stable oxide film in an oxidizing environment which spontaneously contributes to the passivation or repassivation procedure to prevent corrosion and promote biocompatibility of the metal. Ti6Al4V is the most used titanium alloy (Gepreel and Niinomi, 2013; Dzogbewu et al., 2021). Aluminium increases the strength and decreases the alloy weight while vanadium decreases the alloy proneness to corrosion. Titanium and its alloys have largely been used since the 1980s to replace a missing tooth (Dzogbewu, 2021; Nicholson, 2020).

Zhao et al. (2009) note that, although titanium alloys are good materials, they can fail due to microbial colonisation on the surface of the implant which causes infection. This statement is based on the assumption that the same surface qualities that make Ti-based implants preferred biomaterial also make them susceptible to bacterial infections. The formation of a thin titanium oxide layer under physiological conditions provides an excellent substrate for protein and cell adhesion, which also aids osseointegration. However, these physiological conditions that make Ti-based implants the preferred biomaterial can also provoke bacterial colonization and biofilm formation on titanium-based implant surfaces, hence titanium and its alloys alone are not able to meet every clinical requirement, especially as they cannot prevent infection without appropriate surface modifications (Elias, 2010). Essential oils come to the fore as the preferred antimicrobial agent that can be used to modify the surface of dental implants against implant infection.

Implant failure can occur right at the beginning or at a later stage. Early implant failure occurs before osseointegration (i.e., the direct and stable anchorage of an implant due to the development of bony tissue around the implant), whereas late failure occurs years or decades after insertion (Cillo, 2020). Implants' surfaces are prone to colonization by pathogenic bacteria that cause peri-implant tissue destruction and implant failure (Khammissa et al., 2012). Osseo integrated dental implants have a long- term success rate of over 90%, but they are endangered by pathogenic bacteria colonization (Khammisa et al., 2012), as peri-implant colonization with pathogenic microorganisms causes infection (Pedrazzi et al., 2014). During surgery, implants are prone to bacterial infection from both skin and mucous membranes. Such infection results from a biofilm that forms around the surface of the implant (Nhlapo et al., 2019), which in turn causes dental inflammation (Costerton, 1995; Pedrazzi et al., 2014). This biofilm is a bacterium formed aggregate that forms in the presence of liquid on hard surfaces. Biofilm infestation causes an immune inflammatory reaction in local tissue and could lead to inflammatory processes in gums known as gingivitis or peri-implant mucositis (Costerton, 1995; Pedrazzi et al., 2014). Peri-implatitis, which is caused by bacterial colonization, is an irreversible inflammation of the soft and hard peri-implant tissues (Cillo, 2020). Gingivitis is the slightest form of periodontal diseases that are caused by a bacteria biofilm that gathers on the teeth adjacent to the gums. Periodontitis causes loss of connective tissue and bone support and is a major cause of tooth loss (Pihlstrom and Tabak, 2005; Pedrazzi et al., 2014; Cillo, 2020). It is proven that essential oils can be used to prevent such kind of infection (Warnke et al., 2009; Chouhan et al., 2017).

Common Treatment Methods for Biofilm on the Surface of an Implant

Various strategies may be used to avoid infection on titanium implant surfaces such as surface modification and coatings with antibiotics, antimicrobial peptides, inorganic antibacterial metal elements, and antibacterial polymers (Nhlapo et al., 2019; Dzogbewu 2021). Surface modification of implanted devices is an efficient way of lessening the occurrence of implant-related infection. It is a relatively uncomplicated method to modify the interfacial properties of medical devices without disturbing the bulk properties of the material. Surface modification involves using techniques such as matrix supported pulsed laser evaporation to alter the biomaterial surface and to prevent the initial attachment of bacteria. Laser photodynamic, or photothermal elimination of the bacteria flora, appears promising, but it is not available to every clinician, so it may be too specialised to be considered a standard treatment (Warnke et al., 2009; Khatoon et al., 2018).

The use of antimicrobial mouth rinses as a chemical method has become common in the last decade to control biofilm development. Mouth rinses have active ingredients that are used for chemical biofilm control and these ingredients usually include bis-biguanide, essential oils, and 0.12% chlorhexidine gluconate. The most common therapeutic agents discovered in mouth rinses include essential oil components such as thymol, eucalyptol, menthol, and methyl salicylate. The other chemical components are chlorhexidine gluconate, hexetidine, benzalkonium chloride, hydrogen peroxide, cettylpyridinium chloride, and sometimes fluoride, domiphen bromide, and xylitol which are known to be responsible for inhibiting bacterial growth (Pedrazzi et al., 2014). Chlorhexidine reduces 60% biofilm buildup and gingivitis severity in 50−80% of cases. Total anaerobes, total aerobes, Streptococci, and Actinomyces are significantly reduced when the mouth is rinsed with treatments containing 0.12 percent chlorhexidine gluconate.

However, Pedrazzi et al. (2014) found that after both three- and six-month periods, essential oils had delayed biofilm growth in 45−56% of cases and reduced the existing biofilm in 39−48% of cases, whereas a reduction of up to 59% in gingivitis was also observed after their continuous use. However, Pedrazzi et al. (2014) discovered that essential oils delayed biofilm growth in 45-56 % of cases and reduced existing biofilm in 39-48 % of cases after three and six months of use, as well as a reduction in gingivitis of up to 59 % following continuous use. Studies have reported that essential oils alter microbial total mass and cause a decrease in both biofilm activity and biomass (Pedrazzi et al., 2014). The simplest and best known oral care hygiene method is the proper use of a toothbrush to maintain oral health and reduce most oral pathogens. However, this method is not effective enough to maintain good oral hygiene as the toothbrush has difficulty in reaching interproximal areas (Pedrazzi et al., 2014). There are several devices such as dental floss or tape available on the market for use in areas a toothbrush cannot reach (Pedrazzi et al., 2014). Electric and electromagnetic fields have also been explored for the treatment of bacterial colonization as it is known that cells are sensitive to electric fields (Khatoon et al., 2018). However, regardless of a variety of preventative measures, the prevalence of peri-implant diseases is increasing, and therefore the discovery of effective prevention methods seems to be crucial for implant recommendation as well as for the advancement of professional training (Nhlapo et al., 2019). Therefore, the greatest possible treatment for biofilminduced infections is to prevent bacteria colonization at the initial attachment stage to prevent any infection from the beginning.

Bacteria have a cell membrane that serves as a blockade between the cytoplasm and the external environment. Gram-positive bacteria consist of a tough and rigid mesh cell wall, whereas Gram-negative bacteria have a thin cell wall surrounded by an outer membrane that is an additional protective layer (Kapoor et al., 2017). The cell membrane remains important for the existence of bacteria, whereas the cytoplasm exists to prevent ions from flowing into and out of the cells of bacteria. When bacteria are treated with antimicrobial agents such as essential oils, these oils degrade the cell membrane which is detrimental to the cytoplasmic membrane. This causes cytoplasmic coagulation, thus damaging the membrane proteins and increasing penetrability, which leads to the leaking of cell substances and its subsequent destruction (Nazzaro et al., 2013; Chouhan et al., 2017). The cytoplasmic membrane of a bacterium cell has a pump function that takes antimicrobial agents out of the cell, which is referred to as the efflux pump mechanism. However, essential oils degrade the entire cell, thus making it difficult for bacteria to fight against them (Nazzaro et al., 2013; Chouhan et al., 2017; Yang et al., 2020). It is known that essential oils and their components act upon a variety of targets, such as the cell membrane and cytoplasm. In some cases, they totally change the structure of the bacterial cells (Nazzaro et al., 2013; Swamy et al., 2016). However, the chemical components of plants' essential oils are different, and these differences are linked to the nature of their antimicrobial activities against diverse pathogenic microorganisms (Voon et al., 2012; Swamy et al., 2016)., Essential oils have a hydrophobic nature, which is what allows them to penetrate microbial cells. Essential oils are regarded as rich in phenolics that enable them to penetrate the phospholipids bilayer of the bacteria cell wall and to bind with proteins. This prevents bacteria cells from executing their normal functions (Nazzaro et al., 2013; Chouhan et al., 2017).

It is therefore envisaged that continual research which will lead to diverse applications of essential oils as antibacterial agents in dentistry would prevent dental implant failure.

Conclusion and future directions

Oral illnesses remain a serious public health concern that must be addressed, particularly in underprivileged populations. Dental caries, which manifests as tooth decay, tooth loss, periodontal disease and cancer of the lips, is the most frequent and serious oral illness worldwide. Individuals lose teeth (or teeth) as a result of bacterial growth in the mouth. Dental implantology was developed to restore the missing tooth. A dental implant is used to replace a lost tooth and can be used to support a crown, denture or bridge. Endosseous implants, on the other hand, might fail due to implant infection either early or late in the implantation process. Periodontitis and peri-implantitis are inflammatory disorders caused by periodontal pathogenic bacteria that destroy the peri-implant tissue that supports them. The inflammation spreads along with the germs on the surface of the tooth or implant.

To prevent infection after dental implant installation, treatment methods such as prophylactic systemic antibiotic regimens have been proposed. However, microorganisms have developed antibiotic resistance due to the overuse of antibiotics by individuals. Medicinal plants, such as essential oils, have shown to be effective at inhibiting the growth of drug-resistant bacteria strains that are difficult to treat with conventional antibiotics. Essential oils are utilized to treat cancer and cardiovascular disorders as antimicrobial, anti-antioxidant and anti-diabetic agents. The effects of essential oils on the health and well-being of the oral cavity and dental implants are still unknown. Because of this information gap, researchers have turned to natural chemicals found in aromatic plants that are used in conventional medicine, aromatherapy and cosmetics to find new and effective forms of antimicrobial agents.

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CONFLICTS OF INTEREST

The author does not have conflicts of interest to declare.

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