

HERBAL PRODUCTS AGAINST DENTAL CARIES

Ozgu Ilkcan Karadaglioglu*, Laden Gulec Alagoz

Faculty of Dentistry, Department of Restorative Dentistry, Near East University, Mersin , Turkey.

ABSTRACT

Background: Even after years and developments in healthcare, dental caries is regarded as the most chronic disease in the human population. Dental caries is associated with oral pathogenic bacteria. For this reason, antibacterial agents are used in their treatment. However, these antibacterial agents contain commonly harsh chemicals such as fluoride. People who are conscious of the side effects of fluoride have started to prefer natural antibacterial products. Studies have focused on the therapeutic properties of plants in terms of dentistry and new oral care products have been developed

Objective: This article aims to collect information about using plants against dental caries and review their effects.

Methods: Studies on the antibacterial activity of herbal products in the literature, especially in the last 5 years, have been reviewed.

Discussion: Essential oils and extracts obtained from plants seem good alternatives to the chemical products. Herbal products contain several active biological components and due to these components, they show the effects of inhibiting dental plaque formation and reducing microbial adhesion.

Key words: caries, herbal product, plants, antibacterial, oral care products.

Introduction

People struggle with many chronic diseases every year. Dental infections, such as dental caries are the one of common bacterial diseases in the human population¹. Dental caries is a disease that occurs by the alteration of demineralization-remineralization cycle^{2,3}, destroys tooth structure and it can cause negativities in chewing and aesthetic appearance⁴.

Factors such as cariogenic microflora, fermentable carbohydrates, plaque, and duration play the most effective roles in the formation of dental caries⁵. The bacterial accumulation on dental surfaces known as dental plaque is the reason for dental caries¹. Dental caries does not occur in the absence of dental plaque or fermentable carbohydrate products².

Several studies have proven that the *Streptococcus mutans* (*S.Mutans*) has a higher prevalence in caries containing plaque than healthy tooth surface⁶⁻⁸. Ritz⁹ stated that streptococci follow these precursor type actinomyces, which are dominant for plaque development.

McClure and Hewitt created artificial caries in rats and they observed that dental caries can be inhibited by administration of penicillin in diet and water. This proven application has been extended to other antibiotics and tested on the animals¹⁰. Nowadays, in the fight against dental caries, the use of chemical agents such as alcohols,

chlorhexidine, and antibiotics (penicillin, ampicillin, etc.) are quite common¹¹. However, the treatment methods of dental caries are symptomatic and do not include a preventable approach to bacterial factors that cause dental caries and periodontal diseases¹. Also, resistance to antibiotics may develop against bacteria in biofilm and this may worsen the prognosis of the disease¹². To prevent this situation, efforts are underway to develop new anti-infective agents against microorganisms¹³.

Tooth brushing can prevent caries, periodontal problems, and gingivitis. However, the use of tooth brushing as a traditional method of oral hygiene for many individuals shows inadequate results in the long term. To provide solutions for plaque-mediated diseases, it has been suggested that prophylactic antimicrobial agents can be added to oral health products¹⁴. The viability of bacteria in the biofilm is affected by antibacterial agents¹⁵. The use of antibacterial chemotherapeutic agents has been specifically proposed to reduce levels of oral bacteria, such as *Streptococcus mutans*¹⁶. It has been reported by Miller that antiseptics can be used as an active agent in the prevention of caries¹⁷.

World Health Organization (WHO), American Dental Association (ADA), and the World Dental Federation (FDI) recommend kinds of toothpaste containing fluoride and triclosan¹⁸. The use of toothpaste containing fluoride and triclosan indeed has benefits. However, excessive use of chemical and synthetic products is harmful. The use of

products containing fluoride can cause changes in the intestinal and oral flora and even oral cancer, vomiting, and dental staining¹⁹. Other chemicals such as chlorhexidine and amine fluoride cause toxic effects. Ethanol, another chemical added to oral products, has been reported to cause cancer^{20, 21}. Recently, herbal products have become popular due to various problems created by chemical products in the human body.

Phytotherapy, which means treatment with plants, is a complementary treatment. All or part of the plants is mixed and used for treatment. During this process, care is taken to preserve the original composition of the plant²². When examined in terms of developments in dentistry, phytotherapy is used because of the antimicrobial, anti-inflammatory, analgesic, and sedative properties of plants²³. One of the methods of using plants in the treatment is to obtain essential oils. Essential oils are aromatic liquids with volatile characters and they are obtained from several parts of plants such as leaves, barks, seeds, and roots. Due to their different components which they have, essential oils can show variations of their mechanisms of action²⁴. Their usage areas are quite wide due to their antibacterial, insecticidal, and antifungal effects²⁵. The first studies that obtained information on the existence of antibacterial properties of essential oils were carried out by Dela Croix in 1881. The data obtained from this study led other studies that used essential oils in medicine in the following centuries²⁶.

Some essential oils identified by the American Food and Drug Administration have been generally described as generally recognized as safe/GRAS (Generally Recognized as Safe) food additives or taste-smell additives²⁷. Essential oils have irritant, antitussive, rubefian, nervinatic, carminative, emmenagogue, diuretic, anthelmintic, antiseptic, anti-inflammatory, antifungal, antioxidant, and antibacterial properties^{28, 29}. Essential oils show antibacterial activity against various bacteria, including *S. Mutans*³⁰.

As mentioned above, chemical treatments have positive properties besides negative properties. Also, bacteria can develop resistance to these agents. For this reason, oral health products such as mouth rinse and kinds of toothpaste containing various products from plants including essential oils have been developed as an alternative to chemical treatments.

This article aims to discuss the effects of the products containing essential oils on *S.mutans*, one of the pathogens that cause dental caries.

Herbal Toothpaste

S.mutans is an oral pathogen associated with the development of caries³¹. Therefore, if the oral products to be used have antibacterial properties, they may be effective against pathogens. Commercial toothpaste is using as an effective antimicrobial agents against oral microorganisms.

Fluoride is known for its effect on caries prevention and fluoride-containing toothpaste is widely preferred as anti-cariogenic agents³². However, due to their harmful effects on organisms, herbal toothpaste can be preferred rather than toothpaste containing harsh chemicals.

Studies have been conducted about plant extracts, essential oils, and phytochemicals for their ability to prevent bacterial adhesion. Some researchers compared fluoride-containing toothpaste and herbal toothpaste^{33, 34}.

In a study conducted in 2019, the researchers compared fluoride-containing toothpaste and three herbal toothpaste according to the ability to prevent caries development before and after the addition of essential oils obtained from *Origanum dubium* (*O.dubium*) and *Cinnamomum cassia* (*C.cassia*). They observed the close results each other for fluoride-containing toothpaste and two herbal toothpaste before addition. The other herbal toothpaste produced for babies did not show any antibacterial activity. After the addition of essential oil, the group with the highest activity belonged to the paste produced for babies, especially the group containing *C.cassia* essential oil³⁵. In a study conducted by Korkmaz et al.³⁶ in 2019, the antibacterial activities of three different commercial herbal toothpaste (*Aloe vera* L, *Fragaria vesca* L.) investigated against two pathogens that cause infections in the oral cavity. According to the results, these herbal kinds of toothpaste were effective in reducing plaque accumulation.

Herbal Mouthwashes

People generally are not successful in removing dental plaque while tooth brushing. Mouthwashes can be added to the daily care routine to control the bacterial plaque to restrain periodontal diseases³⁷. Mouthwashes are chemotherapeutic agents that can deliver the chemicals they contain to all hard and soft surfaces in the mouth and these agents can show activity. Chlorhexidine, one of the chemotherapeutic agents used in mouthwashes, is accepted as the “gold standard” and it is often preferred as a positive control group to compare other materials³⁸. However, besides its benefits, chlorhexidine has several side effects, such as erosion of oral mucosa, staining of the teeth, and unpleasant taste. Therefore, there is a need for an agent that

will neutralize the harmful effects of chlorhexidine and act at least as much³⁸. As an alternative to chlorhexidine, various studies using natural products and traditional plants have been reported^{39, 40}.

In their clinical trials in 2020, Kamath et al.⁴¹ compared the effects of 4 types of mouthwash (two herbal containing mouthwashes, one containing chlorhexidine, and one placebo) on children aged between 8 and 14. According to the results of the study, although chlorhexidine is the most effective mouthwash, it has been observed that mouthwashes with herbal ingredients are effective.

Researchers investigated the number of bacteria in saliva, buffering capacity changes in the pH of saliva when using herbal mouthwash and chlorhexidine. Chlorhexidine was found to be more effective than herbal mouthwash but herbal containing mouthwash was increased buffering capacity and the pH and decreased the number of bacteria in saliva⁴².

In a study conducted in 2018, herbal mouth rinse was compared with chlorhexidine and measured the levels of *S.mutans* in the saliva of children. Researchers observed that the herbal mouthwashes were better than chlorhexidine⁴³.

Khoromian et al.⁴⁴ completed a randomized cross-over clinical trial study in 2020 and they aimed to determine the effect of herbal containing mouthwash on *S.mutans* in oral flora. According to the results obtained from the study, when the volunteers used herbal containing mouthwash, the number of *S.mutans* in saliva were decreased significantly before use.

Use of Herbal Extracts for Remineralization

White spot lesions can define as white opaque areas caused by the loss of minerals on enamel and these areas can be detected clinically. They are frequently observed after orthodontic treatment and they can create retentive areas for plaque due to their irregular surface structure. As a result of carbohydrate-rich dietary, bacterial infection which modified by saliva and poor oral hygiene, demineralization may occur on enamel⁴⁵⁻⁴⁹.

Dental remineralization aims to bring minerals from the environment such as saliva and biofilm into the demineralized tooth area. Minerals are replaced in enamel and dentin⁵⁰.

Silva et al.⁵¹ (2015) created artificial caries and compared the remineralization potential of proanthocyanidin (the major

component of grape seed extract) and fluoride on enamel and dentin of bovine teeth. The grape seed extract was found successful though not as much as fluoride and it can prevent demineralizing in both layers.

In a study conducted by Kim and Jin⁵², in 2018 the remineralizing effect of combining *Galla chinensis* extract with calcium was investigated on dental enamel and antibacterial effects on *S.mutans* biofilm. According to the results, *Galla chinensis* can remineralize the enamel and it exhibited synergy with calcium. Also, it inhibited the acid production of *S.mutans*.

Herbal-based toothpaste can protect the enamel from demineralization according to the components they have. Researchers used commercial herbal toothpaste for observation of protective effects on enamel demineralization *in vitro*. All kinds of toothpaste have some antibacterial effects, but only one of them showed an inhibitor effect on enamel remineralization⁵³. *Salvadora persica* (*S.persica*) or miswak is a plant that grows in the middle east and it is important as mechanical cleaning on oral health for the people of this region. Although it seems to provide mechanical cleaning, the components it contains also help it show chemical activity. Sulfur in its composition shows bactericidal effect⁵⁴ and its compounds may protect against dental caries⁵⁵. At the same time, the essential oil of *S.persica* stimulates the saliva and may activate the buffering system. If the miswak stick is chewed, a saturation of calcium in the saliva may support enamel remineralization⁵⁶. Wassel and Sherief⁵⁷ evaluated the ion releasing and remineralizing effect of propolis, miswak, and chitosan nano-particles based dental varnishes. According to the Knoop hardening tests and scanning electron microscopy images, miswak and chitosan containing varnishes can release ions and gain microhardness to the enamel surfaces.

Tea, especially green tea, is rich in catechins like epigallocatechin gallate, epicatechin gallate, epigallocatechin, epicatechin⁵⁸. Jose et al.⁵⁸ stated in their study, tea was increased in microhardness of enamel through these components. Taha researched in their study the remineralizing effect of green tea against acidic drinks. According to the results they obtained, green tea may help stop the erosive effect of acidic drinks and may support the remineralization⁵⁹.

In traditional Indian culture, oil pulling which uses edible oil as a mouthwash is observed commonly⁶⁰⁻⁶³. The reducing effect of *S.mutans* growth of coconut oil has been proved. Its remineralizing effect also wondered. In a study conducted in

2019, researchers created an artificial remineralizing-demineralizing cycle in in-vitro conditions. The coconut products were applied to the demineralized specimens and these specimens were evaluated using scanning electron microscopy. According to the results, the products obtained from coconut oil, water, and milk- may be an alternative to known remineralizing agents⁶⁴.

Lemon oil is obtained from peels of lemon and containing Limonine as the main component. Researchers stated that these essential oils have antibacterial effects against the cariogenic bacteria and inhibit their properties of cariogenic⁶⁵⁻⁶⁷. This situation has led researchers to research its remineralizing effects also. Ma et al.⁶⁸ have concluded that the lemon essential oil can promote remineralization during the development of early caries and also they found that these essential oils can stabilize its structure against collagen degradation.

Conclusion

When various studies were examined, successful results were obtained when the herbal products were compared with the products considered as the gold standard. Although herbal ingredients are thought to be more harmless than those containing heavy chemicals, more studies are needed to learn the biocompatibility and safety of use. If their bio-reliability is proven, they can be used very effectively in the fight against pathogenic bacteria in the field of dentistry.

References

1. Loesche WJ. Role of Streptococcus mutans in Human Dental Decay. *Microbiol. Rev.* 1986; 50(4): 353-380.
2. Zero DT. Dental caries process. *Dent. Clin. N. Am.* 1999; 43(4): 635-664.
3. Featherstone JDB. Dental caries: a dynamic disease process. *Aust. Dent. J.* 2008; 53(3): 286-291. doi: <https://doi.org/10.1111/j.1834-7819.2008.00064.x>
4. Petersen PE. The World Oral Health Report 2003: continuous improvement of oral health in the 21st century—the approach of the WHO Global Oral Health Programme. *Community Dent. Oral Epidemiol.* 2003; 31(1): 3-24. doi: <https://doi.org/10.1046/j.2003.com122.x>
5. Selwitz RH, Ismail AI, Pitts NB. Dental caries. *Lancet* 2007; 369(9555): 51-55. doi: [https://doi.org/10.1016/s0140-6736\(07\)60031-2](https://doi.org/10.1016/s0140-6736(07)60031-2).
6. Van Houte J, Backer Dirks O, Stoppelaar JD, de Jansen HM. Iodophilic polysaccharide-producing bacteria and dental caries in children consuming fluoridated and non-fluoridated drinking water. *Caries Res.* 1969; 3(2): 178-189. doi: <https://doi.org/10.1159/000259581>
7. Littleton NW, Kakehashi S, Fitzgerald RJ. Recovery of specific 'caries-inducing' streptococci from carious lesions in the teeth of children. *Arch. Oral. Biol.* 1970; 15(5):461-463. doi: [https://doi.org/10.1016/0003-9969\(70\)90073-7](https://doi.org/10.1016/0003-9969(70)90073-7)
8. Loesche WJ, Straffon LH. Longitudinal investigation of the role of Streptococcus mutans in human fissure decay. *Infect. Immun.* 1979; 26(2):498-507. doi: <https://doi.org/10.1128/iai.26.2.498-507.1979>
9. Ritz HL. Microbial population shifts in developing human dental plaque. *Arch. Oral Biol.* 1967; 12(12): 1561-1568. doi: [https://doi.org/10.1016/0003-9969\(67\)90190-2](https://doi.org/10.1016/0003-9969(67)90190-2)
10. McClure FJ, Hewitt WL. The relation of penicillin to induced rat dental caries and oral L. acidophilus. *J. Dent. Res.* 1946; 25(6): 441-443. doi: <https://doi.org/10.1177/00220345460250060401>
11. Gazzaneo LRS De Lucena RFP de Albuquerque UP. Knowledge and use of medicinal plants by local specialists in a region of Atlantic Forest in the state of Pernambuco (Northeastern Brazil). *J. Ethnobiol. Ethnomed.* 2005; 1, 9. doi: <https://doi.org/10.1186/1746-4269-1-9>
12. Gilbert P, Das J, Foley I. Biofilm susceptibility to antimicrobials. *Adv. Dent. Res.* 1997; 11(1): 160-167. doi: <https://doi.org/10.1177/08959374970110010701>
13. Projan SJ, Youngman PJ. Antimicrobials: New solutions badly needed. *Curr. Opin. Microbiol.* 2002; 5(5): 463-465. doi: [https://doi.org/10.1016/s1369-5274\(02\)00364-8](https://doi.org/10.1016/s1369-5274(02)00364-8)
14. Addy M. Chemical plaque control. In: Kieser BJ, editor. *Periodontics: a practical approach.* London: Wright Publishing Company; 1990.
15. Mandel ID. Chemotherapeutic agents for controlling plaque and gingivitis. *J. Clin. Periodontol.* 1988; 15(8): 488-498. doi: <https://doi.org/10.1111/j.1600-051x.1988.tb01020.x>
16. Menendez A, Li F, Michalek SM, Kirk K, Makhija SK, Childers NK. Comparative analysis of the antibacterial effects of combined mouth rinses on Streptococcus mutans. *Oral Microbiol. Immunol.* 2005; 20(1): 31-34. doi: <https://doi.org/10.1111/j.1399-302x.2004.00189.x>
17. Baehni PC, Takeuchi Y. Anti-plaque agents in the prevention of biofilm-associated oral diseases. *Oral Dis.* 2003; 9(Suppl 1): 23-29. doi: <https://doi.org/10.1034/j.1601-0825.9.s1.5.x>
18. Morris AJ, Steele J, White DA. Adult dental health survey: The oral cleanliness and periodontal health of

- UK adults in 1998. *Br. Dent J.* 2001; 191(4): 186–192. doi: <https://doi.org/10.1038/sj.bdj.4801135>
19. Al-Quran, S. Ethnobotanical survey of folk toxic plants in southern part of Jordan. *Toxicon* 2005; 46(2): 119–129. doi: <https://doi.org/10.1016/j.toxicon.2005.04.010>
 20. McCullough, MJ, Farah CS. The role of alcohol in oral carcinogenesis with particular reference to alcohol-containing mouthwashes. *Aust. Dent. J.* 2008; 53(4):302–305. doi: <https://doi.org/10.1111/j.1834-7819.2008.00070.x>
 21. Palombo EA. Traditional medicinal plant extracts and natural products with activity against oral bacteria: Potential application in the prevention and treatment of oral diseases. *J. Evid. Based Complement. Altern. Med.* 2011; 2011:680354. doi: <https://doi.org/10.1093/ecam/nep067>
 22. Falzon CC, Balabanova A. Phytotherapy: An introduction to herbal medicine. *Prim. Care.* 2017; 44(2): 217–227. doi: <https://doi.org/10.1016/j.pop.2017.02.001>
 23. Groppo FC, Bergamaschi CDC, Cogo K, Franz-Montan M, Motta RHL, Andrade, EDD. Use of phytotherapy in dentistry. *Phyther. Res.* 2008; 22(8):993–998. doi: <https://doi.org/10.1002/ptr.2471>
 24. Calsamiglia M, Busquet PW, Cardozo L, Castillejos L, Ferret A. Invited review: Essential oils as modifiers of rumen microbial fermentation. *J. Dairy Sci.* 2007; 90(6): 2580–2595. Doi: <https://doi.org/10.3168/jds.2006-644>.
 25. Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils—A review. *Food Chem. Toxicol.* 2008; 46(2):446–475. doi: <https://doi.org/10.1016/j.fct.2007.09.106>.
 26. Çelen S. Composition and the in-vitro Antibacterial and Antifungal Activities of The Essential Oils of Four Thymus Species in Turkey. Balikesir University Balikesir University, Institute of Science, Department of Biology M Sci Thesis, Balikesir, 2006.
 27. Burt S. Essential oils: their antibacterial properties and potential applications in foods—a review. *Int. J. Food Microbiol* 2004; 94(3): 223–253. doi: <https://doi.org/10.1016/j.ijfoodmicro.2004.03.022>
 28. Faleiro ML, Miguel MG, Ladeiro F, Venancio F, Tavares R, Brito JC, Figueiredo AC, Barroso JG, Pedro LG. Antimicrobial activity of essential oils isolated from Portuguese endemic species of Thymus. *Letters in applied microbiology.* 2003 Jan;36(1):35–40. doi: <https://doi.org/10.1046/j.1472-765x.2003.01259.x>
 29. Bounatirou S, Smiti S, Miguel MG, Faleiro L, Rejeb MN, Neffati M, Costa MM, Figueiredo AC, Barroso JG, Pedro LG. Chemical composition, antioxidant and antibacterial activities of the essential oils isolated from Tunisian Thymus capitatus Hoff. et Link. *Food chemistry.* 2007 Jan 1;105(1):146–55. doi: <https://doi.org/10.1016/j.foodchem.2007.03.059>
 30. Al-Mariri A, Safi M. In vitro antibacterial activity of several plant extracts and oils against some gram-negative bacteria. *Iran J Medi Sci* 2014; 39(1): 36–43.
 31. George D, Bhat SS, Antony B. Comparative evaluation of the antimicrobial efficacy of aloe vera tooth gel and two popular commercial toothpastes: An in vitro study. *Gen. Dent.* 2009; 57(3): 238–241.
 32. Ten Cate JM. Current concepts on the theories of the mechanism of action of fluoride. *Acta Odontol. Scand.* 1999; 57(6): 325–329. doi: <https://doi.org/10.1080/000163599428562>
 33. Randall JP, Seow WK, Walsh LJ. Antibacterial activity of fluoride compounds and herbal toothpastes on Streptococcus mutans: An in vitro study. *Aust. Dent. J.* 2015; 60(3):368–374. doi: <https://doi.org/10.1111/adj.12247>
 34. Bhattacharjee S, Nath S, Bhattacharjee P, Chouhan M, Deb B. Efficacy of Toothpastes on Bacteria Isolated from Oral Cavity. *Int. J. Med. Public Health* 2018; 8(2): 89–92. doi: <http://dx.doi.org/10.5530/ijmedph.2018.2.19>
 35. Karadağlıoğlu Öİ, Ulusoy N, Başer KHC, Hanoğlu A, Şık İ. Antibacterial Activities of Herbal Toothpastes Combined with Essential Oils against Streptococcus mutans. *Pathogens.* 2019; 8(1): 20. doi: <https://doi.org/10.3390/pathogens8010020>
 36. Korkmaz FM, Ozel MB, Tuzuner T, Korkmaz B, Yayli N. Antimicrobial activity and volatile constituent analysis of three commercial herbal toothpastes containing Aloe vera L. and Fragaria vesca L. extracts. *Niger. J. Clin. Pract.* 2019; 22(5): 718–726. doi: [10.4103/njcp.njcp_557_18](https://doi.org/10.4103/njcp.njcp_557_18)
 37. Barnett ML. The role of therapeutic antimicrobial mouth rinses in clinical practice: control of supragingival plaque and gingivitis. *J. Am. Dent. Assoc.* 2003; 134(6): 699–704. doi: <https://doi.org/10.14219/jada.archive.2003.0255>
 38. Lakade LS, Shah P, Shirol D. Comparison of antimicrobial efficacy of chlorhexidine and combination mouth rinse in reducing the Mutans streptococcus count in plaque. *J. Indian Soc. Pedod. Prev. Dent.* 2014; 32(2): 91–96. doi: [10.4103/0970-4388.130780](https://doi.org/10.4103/0970-4388.130780)

39. Cowan M. Plant products as antimicrobial agents. *Clin. Microbiol. Rev.* 1999; 12(4): 564-582. doi: 10.1128/CMR.12.4.564
40. Kalembe D, Kunicka A. Antibacterial and antifungal properties of essential oils. *Curr. Med. Chem.* 2003; 10(10): 813-829. doi: <https://doi.org/10.2174/0929867033457719>
41. Kamath NP, Tandon S, Nayak R, Naidu S, Anand PS, Kamath, YS. The effect of aloe vera and tea tree oil mouthwashes on the oral health of school children. *Eur. Arch. Paediatr. Dent.* 2020; 21, 61-66. doi: <https://doi.org/10.1007/s40368-019-00445-5>
42. Nagalingam M, Vikramathithan M, Gandhi AD, Rajeshkumar S. Evaluation of herbal and chemical-based mouthwash against oral pathogens. *Drug Invent. Today.* 2019; 11(1): 147-151.
43. Shah S, Bargale S, Dave BH, Deshpande A, Kariya PB, Karri A. Comparison of antimicrobial efficacy of (between) 0.2% chlorhexidine and herbal mouthwash on salivary *Streptococcus mutans*: A randomized controlled pilot study. *Contemp. Clin. Dent.* 2018; 9(3): 440-445. doi: https://dx.doi.org/10.4103%2Fcccd.ccd_264_18
44. Khoromian TS, Jafari A, Marash SMA, Faramarzi NS, Farid M, Ansari M. The effect of antimicrobial activity of *Teucrium Polium* on Oral *Streptococcus Mutans*: a randomized cross-over clinical trial study. *BMC Oral Health.* 2020; 20(2020): 1-8. doi: <https://doi.org/10.1186/s12903-020-01116-4>
45. Tufekci E, Dixon JS, Gunsolley JC, Lindauer SJ. Prevalence of white spot lesions during orthodontic treatment with fixed appliances. *Angle Orthod.* 2011; 81(2):206-210. doi: <https://doi.org/10.2319/051710-262.1>
46. Jung WS, Kim H, Park SY, Cho EJ, Ahn SJ. Quantitative analysis of changes in salivary mutans streptococci after orthodontic treatment. *Am J Orthod. Dentofac.* 2014; 145(5): 603-609. doi: <https://doi.org/10.1016/j.ajodo.2013.12.025>
47. Sonesson M, Twetman S, Bondemark L. Effectiveness of high-fluoride toothpaste on enamel demineralization during orthodontic treatment—a multicenter randomized controlled trial. *Eur. J. Orthod.* 2014; 36(6): 678-682. doi: <https://doi.org/10.1093/ejo/cjt096>
48. Sadeq A, Risk JM, Pender N, Higham SM., Valappil SP. Evaluation of the co-existence of the red fluorescent plaque bacteria *P. gingivalis* with *S. gordonii* and *S. mutans* in white spot lesion formation during orthodontic treatment. *Photodiagn. Photodyn.* 2015; 12(2): 232-237. doi: <https://doi.org/10.1016/j.pdpdt.2015.03.001>
49. Manavi K, Naik V, Bhatt K. Microbial colonization on elastomeric modules during orthodontic treatment: an in vivo study. *Ind. J. Orthod. Dentofac. Res.* 2016. 2(2): 43-49.
50. Cochrane NJ, Cai F, Huq NL, Burrow MF, Reynold EC. New approaches to enhanced remineralization of tooth enamel. *J. Dent. Res.* 2010; 89(11): 1187–1197. doi: <https://doi.org/10.1177%2F0022034510376046>
51. Silva APP, Gonçalves RS, Borges AFS, Bedran-Russo AK, Shinohara MS. Effectiveness of plant-derived proanthocyanidins on demineralization on enamel and dentin under artificial cariogenic challenge. *J. Appl. Oral Sci.* 2015; 23(3): 302-309. doi: <https://doi.org/10.1590/1678-775720140304>
52. Kim EJ, Jin BH. *Galla chinensis* extracts and calcium induce remineralization and antibacterial effects of enamel in a *Streptococcus mutans* biofilm model. *J. Korean. Acad. Oral Health.* 2018. 42(3): 90-96.
53. Braga AS, Girotti LD, de Melo Simas LL, Pires JG, Pelá VT, Buzalaf MA, Magalhães AC. Effect of commercial herbal toothpastes and mouth rinses on the prevention of enamel demineralization using a microcosm biofilm model. *Biofouling.* 2019 Aug 9;35(7):796-804. doi: <https://doi.org/10.1080/08927014.2019.1662897>
54. Al Samh DAA. In vitro study of the antimicrobial activity and toxicity of the Miswak extract as an endodontic irrigating solution. *J. Dent. Res.* 1996; 75(5):1278.
55. Ababneh H. The effect of the extract of the miswak (chewing sticks) used in Jordan and the Middle East on oral bacteria. *Int. Dent. J.* 1995; 45(3): 218-222.
56. Gazi MI, Davies TJ, Al-Bagieh N, Cox SW. The immediate-and medium-term effects of Meswak on the composition of mixed saliva. *J. Clin. Periodontol.* 1992; 19(2): 113-117. doi: <https://doi.org/10.1111/j.1600-051X.1992.tb00449.x>
57. Wassel MO, Sherief DI. Ion release and enamel remineralizing potential of miswak, propolis, and chitosan nano-particles based dental varnishes. *Pediatr. Dent.* 2019; 29(1): 1-10. doi: <https://doi.org/10.1016/j.pdj.2018.12.004>
58. Jose P, Sanjeev K, Sekar M. Effect of green and white tea pretreatment on remineralization of demineralized dentin by CPP-ACFP-an in-vitro microhardness analysis. *J. Clin. Diagnostic Res.* 2016; 10(4): ZC85-ZC89. doi: <https://dx.doi.org/10.7860%2FJCDR%2F2016%2F16038.7674>

59. Taha RM. Effect of green tea on enamel remineralization of teeth immersed in Pepsi. *Egypt Dent. J.* 2019; 65(4): 3439-3444. doi: <https://dx.doi.org/10.21608/edj.2019.74792>
60. Asokan S, Kumar RS, Emmadi P, Raghuraman R, Sivakumar N. Effect of oil pulling on halitosis and microorganisms causing halitosis: A randomized controlled pilot trial. *J. Indian. Soc. Pedod. Prev. Dent.* 2011; 29(2): 90-94. doi: 10.4103/0970-4388.84678
61. Sood P, Aruna Devi M, Narang R, Swathi V, Makkarak DK. Comparative efficacy of oil pulling and chlorhexidine on oral malodor: A randomized controlled trial. *J Clin. Diagnostic Res.* 2014; 8(11): ZC18-ZC21. doi: <https://dx.doi.org/10.7860%2FJCDR%2F2014%2F9393.5112>
62. Peedikayil FC, Sreenivasan P, Narayanan A. Effect of coconut oil in plaque related gingivitis—A preliminary report. *Niger. J. Med.* 2015; 56(2): 143-147. doi: <https://dx.doi.org/10.4103%2F0300-1652.153406>
63. Kaushik M, Reddy P, Sharma R, Udameshi P, Mehra N, Marwaha A. The effect of coconut oil pulling on Streptococcus mutans count in saliva in comparison with chlorhexidine mouthwash. *J. Contemp. Dent. Pract.* 2016; 17(1): 38-41. doi: 10.5005/jp-journals-10024-1800
64. Rahamat SF, Abd Manan WNH, Jalaludin AA, Abllah Z. Enamel subsurface remineralization potential of virgin coconut oil, coconut milk, and coconut water. *Mater Today.* 2019; 16(4): 2238-2244. doi: <https://doi.org/10.1016/j.matpr.2019.06.116>
65. Han H, Zhang XY, Yang LJ. Effect of lemon peel extracts on the growth of cariogenic bacteria. *J. Oral Sci. Res.* 2012; 28: 117-120.
66. Liu Y, Zhang X, Wang Y, Chen F, Yu Z, Wang L, Chen S, Guo M. Effect of citrus lemon oil on growth and adherence of Streptococcus mutans. *World J. Microb. Biot.* 2013; 29:1161-1167. doi: <https://doi.org/10.1007/s11274-013-1275-7>
67. Sun Y, Chen J, Zhang C, Liu Y, Ma L, Zhang X. Effects of sub-minimum inhibitory concentrations of lemon essential oil on the acid tolerance and biofilm formation of Streptococcus mutans. *Arch. Oral Biol.* 2018; 87, 235-241. doi: <https://doi.org/10.1016/j.archoralbio.2017.12.028>
68. Ma L, Chen, J, Han H, Liu P, Wang H, Lin S et al. Effects of lemon essential oil and limonene on the progress of early caries: An in vitro study. *Arch. Oral Biol.* 2020; 111: 104638. doi: <https://doi.org/10.1016/j.archoralbio.2019.104638>.

Corresponding Author

Ozgu Ilkcan Karadaglioglu, DDS, Ph.D.

Near East University Faculty of Dentistry, Near East Boulevard, Mersin, 10, Turkey, Nicosia, Turkish Republic of Northern Cyprus

Email Id: ozguilkcan.orozu @ neu.edu.tr

Tel:+903926802030;

Fax Number: +903926802034;