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Charcoal-containing toothpastes

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ABSTRACT

The importance of having whiter smiles has increased with the increase in people's aesthetic expectations. Patients who wish to have whiter teeth consult their dentist. Whitening treatment or the use of various kinds of toothpaste is recommended according to the condition of the teeth. However, most people seek professional applications and products that they can apply at home to produce whiter teeth. The most important and most common of these products are the whitening kinds of toothpaste. They are used both for the maintenance phase of tooth whitening treatment and to provide whitening with toothpaste. Manufacturers have developed new formulations to meet consumer satisfaction. With newer formulations, new kinds of toothpaste take their place in the market. This article reviews the general content of toothpaste and the recently popular charcoal-containing types of toothpaste.

Introduction

Toothpaste has long been a part of our daily lives. In 500 BC, Indochina provided a recipe for a tooth-cleaning paste (1). Both France and the United States invented flexible lead or tin tubes in 1846, and toothpaste was first sold in bendable tubes in the US and Germany in 1896. In 1873, Colgate began manufacturing toothpaste in jars in the United States. The first fluoride toothpaste was introduced in the United States in 1955 (1).

Toothpaste has always been offered to consumers as changing and developing oral hygiene products. The most common and simplest method for providing oral dental care is mechanical cleaning of the teeth using toothbrushes and interface brushes. Toothpaste is used to increase the mechanical cleaning efficiency of toothbrushes and to obtain additional effects such as whitening. Because of this state, it can be ensured that the teeth are protected from plaque and tooth decay (2).

The oral hygiene products market aims to continuously improve the content of existing products and to develop new products to satisfy the expectations of consumers. Although toothpaste contains all basic active ingredients that protect from plaque and decay, various substances have recently been added to them (3).

The most common issue that makes patients disturbed is the discoloration of the teeth. Therefore, the ingredients added to toothpaste are formed according to consumer demands.

Due to these demands for tooth-whitening products and many new-toothpaste formations have been created to remove or prevent extrinsic stains (4).

Manufacturers claim that toothpaste and powders containing charcoal, which have recently become popular, have teeth-whitening properties to prevent the recurrence of discoloration (5).

This review aimed to provide an overview of toothpaste and to bring together studies related to the promised properties of charcoal toothpaste (their effects on tooth structure are also included), which have become popular recently.

Content of the toothpaste

1. Abrasives

Abrasives contained in toothpaste physically maintain the removal of tooth extrinsic stains (6). The ideal toothpaste should have low abrasive properties and obstructive tubules (7). The corrosive system must be insoluble in liquid, inert and non-toxic. Calcium carbonate, dicalcium phosphate dihydrate, alumina, silica, and sodium bicarbonate are the most frequently used abrasives in toothpaste production (8).

The abrasiveness of toothpaste depends on the characteristics of abrasives and tooth brushing parameters. Such as particle shape, size, and hardness, as well as the tooth brushing technique, the hardness of the toothbrush, the direction, and the number of brush strokes (9). Additionally, the use of abrasives, detergents, and both add different abrasive properties (6).

2. Humectants

Toothpaste is in the form of a mixture of powder and water. When the tube opens, toothpaste hardens in a short time regardless of water content (9). To regulate this process, humectants are added. Glycerin, sorbitol, propylene glycol, and mannitol are used as humectants (8,9). Among these, glycerin and sorbitol are the most common (10).

3. Surfactant

Toothbrush bristles remove debris and plaque, loose material is removed with the help of the foaming effect of soaps. Soaps left their place with surfactants due to their various disadvantages. Sodium lauryl sulfate (SLS) is the most widely used surfactant today. SLS anti-plaque effect is provided by killing microorganisms, reducing surface energy, and denaturing protein (10).

4. Viscosity and rheology modifiers

They are responsible for ensuring the stability and consistency of the toothpaste. They are responsible for pasting the toothpaste and its stability on the toothbrush (10). Frequently used binders are carrageenans alginate, sodium carboxymethyl cellulose, magnesium aluminum silicate, sodium magnesium silicate, and colloidal silicate (8).

5. Sweetening agents

One of the sweetening agents added to toothpaste is soluble saccharin. Also, mint spectrum, anise, lemon, eucalyptus, and others can be used (8). Several sweetening agents such as menthol show an antimicrobial effect. The concentration of menthol in toothpaste is between 0.1-0.5%. It is a kind of alcohol widely contained in many foods, cosmetics, soaps, and toothpaste. It has been reported that menthol can cause asthma and urticaria (10).

6. Therapeutic agents

Toothpaste is the most suitable tool that can be used to ensure oral health. Different therapeutic agents can be added to it. These agents can be classified as caries prevention agents, agents that prevent plaque formation, agents with antibacterial properties, agents that reduce calculus formation, agents that relieve tooth sensitivity, and whitening agents (8).

a) Anti-caries agents in toothpaste

Fluoride toothpaste helps prevent caries, according to a systematic review (11). Different types of fluoride have been used in toothpaste formulations, including amine fluoride, stannous fluoride, sodium fluoride, and sodium monofluorophosphate. Although there has been substantial discussion about the relative efficiency of these distinct fluoride salts (12), a systematic evaluation revealed that they were all equally beneficial (11).

Toothpaste with fluoride concentrations greater than 1.500 ppm is designated as prescription medication and should only be used to treat those over the age of 10 who are at high risk of caries, such as those who have a dry mouth or have root surface caries. Calcium, phosphorous (phosphates; trimetaphosphates, pyrophosphates, glycerophosphates), metals (zinc, tin, aluminum, iron, manganese, molybdenum), and different anti-microbials are all non-fluoride caries inhibitors in toothpaste formulations. A dental plaque containing calcium carbonate has pH-raising characteristics and may help with remineralization by increasing plaque calcium levels (13).

b) Anti-plaque agents in toothpaste

Most oral anti-plaque agents are antiseptics or antimicrobials that are used to prevent biofilm adhesion, reduce bacterial development, or eliminate and/or modify the pathogenicity of tooth plaque. Anti-plaque agents with adsorption and long-term retention on oral surfaces are the most effective. They should have a broad anti-bacterial range with low toxicity, as well as be compatible with other toothpaste constituents (13).

Triclosan (2,4,4’ trichlor-2’-hydroxydiphenyl ether) is a non-ionic chlorinated bisphenol that is commonly used in personal care products such as deodorants and soaps. It is safe, effective, and well-tolerated. It’s safe to use with toothpaste fluoride and the environment. Active chemicals are present, as well as anti-inflammatory properties. Trichlorosan, on the other hand, has only modest persistence and does not last long enough to have a major anti-bacterial impact. Its oral retention is greatly improved when coupled with a co-polymer, polyvinylmethyl ether maleic acid (PVM/MA or Gantrez) (13).

Concerning the sensitive bacteria, triclosan inhibits the enoyl-reductase enzymes of type 2 fatty acid synthases, causing damage to the cytoplasmic membrane and leaking. It offers a broad anti-microbial spectrum and a considerable anti-plaque impact without staining the teeth. Systematic reviews of six-month clinical studies found that triclosan and copolymer formulations significantly improved plaque control and periodontal health (14,15). Plaque control and gingival health can also be improved with toothpaste-containing triclosan and zinc citrate (13). According to a systematic review, stannous fluoride toothpaste enhanced plaque control and gingivitis (16). Herbal toothpaste has a much higher anti-plaque activity than conventional toothpaste occasionally (17). Both plaque and gingivitis have been observed to be inhibited by a zinc citrate/bromochlorophene/triglyceride composition (18).

c) Anti-calculus toothpaste

Supragingival calculus is a mineralized plaque and inhibiting mineralization with crystal growth inhibitors is one way to regulate it. Inhibitors include pyrophosphates, phosphonates, zinc salts, and substances such as a copolymer of methyl vinyl ether and maleic anhydride (13). In a clinical experiment, using toothpaste with zinc citrate trihydrate and triclosan on a 1450 ppm F silica base reduced calculus (19). Several studies have found that dentifrices containing 3.3 percent-soluble pyrophosphates considerably reduce calculus considerably (20,21). It has been demonstrated that adding copolymer (polyvinyl ether and MA) to pyrophosphate-containing formulations improves their efficacy in reducing calculus (22). Studies have shown that triclosan/copolymer toothpaste is effective in reducing calculus (23).

d) Desensitizing toothpaste

Gingival recession exposes root surfaces, which are a major risk factor for dentin root sensitivity, and is often aggravated following periodontal treatment. To treat sensitivity, two types of products are used: those that interfere with neural impulse transmission and those that block and occlude the dentinal tubules. In several countries, potassium nitrate (5%), potassium chloride (3.75%), and potassium citrate (5.5%) are frequently used since each of these salts contains 2 percent potassium ions, which impedes neuronal transmission. Potassium-based toothpaste should be used twice daily for at least two weeks to obtain measurable sensitivity decreases, according to clinical trials. Compared to conventional fluoride toothpaste, clinical data show that all three types of potassium help lower sensitivity (24,25). The idea of tubule closure is present in both strontium chloride and stannous fluoride. After four weeks of twice-daily use, these products show significant reductions in hypersensitivity. A new formulation has recently been released that works by occluding dentinal tubules. Toothpaste contains 8% arginine, calcium carbonate, and sodium monofluorophosphate (1450-ppm fluoride). This product's effectiveness has been proven in several clinical investigations (26).

e) Whitening toothpaste

Whitening toothpaste has content that offers physical-chemical cleaning that allows the removal of extrinsic stains on the tooth surfaces with daily brushing (3,5,27,28). In the literature (28), these stain-removal ingredients are stated as abrasives, surfactants, calcium chelators, enzymes, and polymers. Traditional whitening toothpaste contains substances such as silica, hydrogen peroxide, or carbamide peroxide that remove stains from the teeth and make them whiter (2,29-31). The whitening ingredients in toothpaste contain herbal origin substances mostly including papaya (papain enzyme), menthol, meswak, clove, salt, and citrus fruits (2).

Toothpaste containing blue covarine provides a whitening effect by depositing covarine on the tooth surface, where it changes the optical properties of the teeth, their appearance is perceived as whiter and measurably whiter. It has also been shown that this toothpaste does not have excessive abrasiveness on enamel or dentin compared to other commercial products (32).

Today, toothpaste containing charcoal is available on the market. The ability of coal powder to absorb teeth stains and unhealthy gums has enabled the intraoral use of coal throughout history. The charcoal used can be made from carbon-rich materials such as wood, nutshell, coconut shells, and bamboo. Coal powders have different degrees of abrasiveness based on their production methods (32).

Effects of charcoal toothpaste

Charcoal or activated carbon is an ingredient found in some toothpaste products (33). Laboratory studies have been conducted on the potential toxicity of charcoal. Teraoka et al. (34) observed that bamboo charcoal could inhibit more HeLa cell proliferation than fetal lung fibroblasts. In studies on bentonite clay in toothpaste containing coal, inhalation of crystalline silica, a mineral in this substance, has a carcinogen effect, but its use and safety in toothpaste have not been reported (35). Additionally, an in vitro study conducted in 2016 showed that bentonite clay induced lung adenocarcinoma cell line proliferation (36).

Since activated charcoal has the ability/capacity to absorb stains, it has attracted attention today (37). Charcoal-containing toothpaste has properties similar to conventional toothpaste in terms of functions. Indeed, the type of toothbrush, brushing technique, and the time spent are considered more important than the ingredients and consistency of the toothpaste. It is stated that activated charcoal is recommended in the product information provided with these charcoal-based toothpaste because it binds to all tooth surface deposits. In formulations

containing this binder clay, it is probably supported by bentonite clay, plaque, bacteria, and extrinsic stains claimed to adhere to the pores of the charcoal (and clay), clearing the tooth surfaces after brushing (32). The charcoal preparation for intraoral use contains various inorganic compounds, flavoring agents, and herbal substances to increase the acceptability of these preparations and to help fight bad breath (32). Because the absorption capacity of charcoal, fluoride, and other active ions, which have diverse effects on teeth, may not show the expected effects in toothpaste containing activated charcoal (38). Due to the absorbent capacity of activated charcoal, it can be used, to extract fluoride from drinking water in communities with a water source with an extremely high fluoride content (38,39). Thus, coal-based toothpaste may have a limited capacity to remineralize the mineral, despite containing fluoride. Therefore, switching from the regular use of fluoride-containing toothpaste to fluoride-free charcoal toothpaste may increase the risk of cavities. Brooks et al. (40) stated that considering the high absorbency of charcoal, any free radical bleaching agent that can chemically reduce the internal staining present in enamel and dentin cannot be found enough. Such toothpaste has the potential to clean hard-to-reach areas and absorb pigments, because of microcoal particles. In addition to these, the shape and size of the coal powders in the paste can become abrasive, increasing the roughness of the enamel (32). Another study by Pertiwi et al. (41) supports this information. However, the ideal toothpaste offers the cleanest teeth with the least abrasiveness (41).

Due to its absorption ability, toothpaste containing activated charcoal may limit the halitosis effect of sweeteners, essential oils, and other ingredients (32). Coal powders that cause gray/black discoloration may occur in patients with periodontal defects and pockets (32). Toothpaste containing activated charcoal provides gradual cleaning of the teeth owing to the absorption ability of the chromophores of the charcoal. Brooks et al. (40) stated that although the possible whitening agent is not supported by scientific evidence, 96% of the pastes containing charcoal claim that they whiten the teeth quite effectively (37).

Vaz et al. (37) showed that all whitening toothpaste (containing activated charcoal, blue covarine, hydrogen peroxide, micro-abrasive, and optimized abrasive) are effective for tooth whitening compared to a toothpaste without a whitening agent (TA) added. Although the whitening effect of all toothpaste increased with continuous use, the best whitening was provided by the paste containing micro-abrasive, followed by the toothpaste-containing hydrogen peroxide and blue covarine. Franco et al. (42) concluded that coal-based tooth powder has a certain degree of a whitening effect, but is not as effective as teeth whitening. Study results show that charcoal may not have any teeth-whitening properties. After 28 days of use, toothpaste with activated charcoal outperformed hydrogen peroxide, blue covariate, and ordinary toothpaste in another trial by Aydın et al. (43). Additionally, toothpaste containing coal has been found to delay the restoration of tooth color when used to delay the recurrence of surface staining on healthy teeth following professional cleaning (40).

Patients wishing to whiten their teeth through brushing have been advised to use one of the well-known brands of regular toothpaste developed for its bleach effect and effectively brush their teeth to remove plaque and external stains, thereby giving their teeth a whiter appearance (32). In their study to compare the color stability and gloss of ceramic stains and glazes with the use of pastes with different amounts of dentin abrasion, Sulaiman et al. (44) concluded that the long-term color stability and gloss retention of colored ceramic restorations remains a clinical concern even in traditional home care products and that charcoal-based toothpaste may be more abrasive than conventional toothpaste. In their study to examine the effectiveness of toothpaste on resin-based CAD/CAM blocks, Aydın et al. (45) reported that there was no statistically significant difference between toothpaste containing activated carbon and other whitening pastes in terms of color improvement.

In another study by Koc Vural et al. (46), in which they compared the effects of different charcoal-based whitening toothpaste on the color, surface roughness, and microhardness of human enamel, there was no difference in the color change between groups after 12 weeks of brushing, and all tested pastes did not show clinically acceptable whitening performance. In another study by Torso et al. (47) to evaluate the effect of charcoal-based toothpaste on the discoloration and surface wear of resin composites, resin composites exposed to charcoal-based toothpaste showed significantly higher discoloration and surface wear than conventional toothpaste. In the study by Dionysopoulos et al. (48) that investigated the effectiveness of charcoal-containing whitening toothpaste and mouthwash on tooth discoloration and enamel changes that may occur after brushing for 90 days, charcoal-containing toothpaste showed a higher whitening effect on teeth than normal toothpaste. However, they concluded that using charcoal-containing mouthwash with whitening toothpaste did not improve discoloration. Additionally, while the use of toothpaste during brushing affected the surface morphology of the enamel differently, whitening mouthwash did not affect these morphological changes (48). Palandi et al. (49) compared the effects of carbamide peroxide and activated charcoal powder mixed with traditional or whitening toothpaste on enamel color and surface. When mixed with traditional and whitening toothpaste, the activated charcoal powder did not increase the color change; however, low-concentration carbamide peroxide induced more color changes than charcoal powder, and charcoal powder alone increased enamel surface roughness.

The charcoal in the paste tends to stick to deposits/contamination and stains on the teeth, build up in gum pockets and change the color of the brush. Also, the tongue tends to darken and must be removed using tongue scrapers. Additionally, coal particles can accumulate along the cavosurface edges of restorations in any marginal defects and defects and complex anatomical structures such as deep cracks. In this situation, it may be harmful to the aesthetic properties of the restorations (32).

Conclusion

This new generation of oral hygiene products, launched in today's fashion, has shown deficient clinical and laboratory data to confirm safety and efficacy claims, according to research, despite its increasing use. Large-scale, redesigned, and comprehensive studies are needed to establish reliable evidence. Its effect on restorations, whitening teeth, and periodontal tissues should be supported by studies. Because of these studies, safer products can be introduced to the market by developing new formulations if necessary. Thus, more reliable kinds of toothpaste are available to patients.

Ethics

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: E.T.A, E.A.O., S.K., Design: E.T.A, E.A.O., S.K., Literature Search: E.T.A, E.A.O., S.K., Writing: E.T.A, E.A.O.

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References

1. Türk Diş Hekimleri Birliği. Diş Hekimliği Tarihçesi. Available from: http://www.tdb.org.tr/sag_menu_yazdir.php?Id=22. Lost Accessed Date: July 10, 2021.
2. Nainan MT, Balan AK, Sharma R, Thomas SS, Deveerappa SB. The comparison of the effects of different whitening toothpastes on the micro hardness of a nano hybrid composite resin. J Conserv Dent. 2014;17:550-554.
3. Kalliath C, Mukunda A, Pynadath M, Venugopal V, Prethweeraj J. Comparison Between the Effect of Commercially Available Chemical Teeth Whitening Paste and Teeth Whitening Paste Containing Ingredients of Herbal Origin on Human Enamel. Ayu. 2018;39:113-117.
4. Joiner A. Review of the extrinsic stain removal and enamel/dentine abrasion by a calcium carbonate and perlite containing whitening toothpaste. Int Dent J. 2006;56:175-180.
5. Greenwall LH, Greenwall-Cohen J, Wilson NHF. Charcoal-containing dentifrices. Br Dent J. 2019;226:697-700.
6. Claydon NC, Moran J, Bosma ML, Shirodaria S, Addy M, Newcombe R. Clinical study to compare the effectiveness of a test whitening toothpaste with a commercial whitening toothpaste at inhibiting dental stain. J Clin Periodontol. 2014;31:1088-1091.
7. Moore C, Addy M. Wear of dentine in vitro by toothpaste abrasives and detergents alone and combined. J Clin Periodontol. 2005;32:1242-1246.
8. Forward GC, James AH, Barnett P, Jackson RJ. Gum health product formulations: what is in them and why? Periodontol 2000. 1997;15:32-39.
9. Harris NO, Garcia-Godoy F. Primary preventive dentistry. 6th ed. Upper Saddle River, NY: Pearson Education; 2004.
10. Dağ C, Özalp N. Ağız-diş sağlığının vazgeçilmezi: diş macunları. Acta Odontol Turc. 2013;30:149-156.
11. Marinho VCC, Chong LY, Worthington HV, Walsh T. Fluoride mouthrinses for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. 2016;7:CD002284.
12. Stookey GK, DePaola PF, Featherstone JDB, et al. A critical review of the relative anticaries efficacy of sodium fluoride and sodium monofluorophosphate dentifrices. Caries Res. 1993;27:337-360.
13. Davies R, Scully C, Preston AJ. Dentifrices - an update. Med Oral Patol Oral Cir Bucal. 2010;15:976-982.
14. Davies RM, Ellwood PP, Davies GM. The effectiveness of a toothpaste containing triclosan and polyvinyl-methylether maleic acid copolymer in improving plaque control and gingival health. J Clin Periodontol. 2004;31:1029-1033.
15. Gunsolley JC. A meta-analysis of six-month studies of antiplaque and antigingivitis agents. J Am Dent Assoc. 2006;137:1649-1657.
16. Paraskevas S, van der Weijden GA. A review of the effects of stannous fluoride on gingivitis. J Clin Periodontol. 2006;33:1-13.
17. Moran J, Addy M, Newcombe R. Comparison of an herbal toothpaste with a fluoride toothpaste on plaque and gingivitis. Clin Prev Dent. 1991;13:12-15.
18. Moran J, Addy M, Corry D, Newcombe RG, Haywood J. A study to assess the plaque inhibitory action of a new zinc citrate toothpaste formulation. J Clin Periodontol. 2001;28:157-161.
19. Chesters RK, O'Mullane DM, Finnerty A, Huntington E, Jones PR. Anti-calculus activity of a toothpaste with microgranules. Oral Dis. 1998;4:213-216.
20. Lobene RR. A clinical study of the anticalculus effect of a dentifrice containing soluble pyrophosphate and sodium fluoride. Clin Prev Dent. 1986;8:5-7.
21. Lobene RR. Anticalculus effect of a dentifrice containing pyrophosphate salts and sodium fluoride. Compendium. 1987;8:175-178.
22. Rosling B, Lindhe J. The anticalculus efficacy of two commercially available anticalculus dentifrices. Compend Suppl. 1987;8:278-282.

23. Volpe AR, Petrone ME, De Vizio W, Davies RM, Proskin HM. A review of plaque, gingivitis, calculus and caries clinical efficacy studies with a fluoride dentiufrice containing triclosan and PVM/MA copolymer. J Clin Dent. 1996;7(Suppl):1-14.

24. Schiff T, Dos Santos M, Laffi S, et al. Efficacy of a dentifrice containing 5% potassium nitrate and 1500 ppm sodium monofluorophosphate in a precipitated calcium carbonate base on dentinal hypersensitivity. J Clin Dent. 1998;9:22-25.

25. Hu D, Zhang YP, Chaknis P, Petrone ME, Volpe AR, DeVizio W. Comparative investigation of the desensitizing efficacy of a new dentifrice containing 5.5% potassium citrate. J Clin Dent. 2004;15:6-10.

26. Ayad F, Ayad N, Delgado E, et al. Comparing the efficacy in providing instant relief of dentin hypersensitivity of a new toothpaste containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride to a benchmark desensitizing toothpaste containing 2% potassium ion and 1450 ppm fluoride, and to a control toothpaste with 1450 ppm fluoride: a three-day clinical study in Mississauga, Canada. J Clin Dent. 2009;20:115-122.

27. Joiner A, Pickles MJ, Matheson JR, Weader E, Noblet E, Huntington E. Whitening toothpastes: effects on tooth stain and enamel. Int Dent J. 2002;52(Suppl 5):412-430.

28. Johansson I, Somasundaran P. Handbook for Cleaning/ Decontamination of Surfaces. 1st ed. Oxford, NY: Elsevier; 2007.

29. Khamverdi Z, Kasraie SH, Rezaei Soufi L, Jebeli S. Comparison of the effects of two whitening toothpastes on microhardness of the enamel and a microhybride composite resin: An in vitro study. J Dent (Tehran). 2010;7:139145.

30. Tao D, Smith RN, Zhang Q, et al. Tooth whitening evaluation of blue covarine containing toothpastes. J Dent. 2017;67:2024.

31. Axelsson P, Odont D. Concept and practice of plaquecontrol. Pediatr Dent. 1981;3(Suppl):101113.

32. Joiner A. A silica toothpaste containing blue covarine: a new technological breakthrough in whitening. Int Dent J. 2009;59:284-288.

33. Garza LA, Thompson G, Cho SH, Berzins DW. Effect of toothbrushing on surface roughness and shade of extrinsically stained pressable ceramic. J Prosthet Dent. 2016;115:489-494.

34. Teraoka F, Hamada Y, Takahashi J. Bamboo charcoal inhibits growth of HeLa cells in vitro. Dent Mater J. 2004;23:633-637.

35. Maxim LD, Niebo R, McConnell EE. Bentonite toxicology and epidemiology: a review. Inhal Toxicol. 2016;28:591-617.

36. Cervini-Silva J, Ramírez-Apan MT, Kaufhold S, Ufer K, Palacios E, Montoya A. Role of bentonite clays on cell growth. Chemosphere. 2016;149:57-61.

37. Vaz VTP, Jubilato DP, Oliveira MRM, et al. Whitening toothpaste containing activated charcoal, blue covarine, hydrogen peroxide or microbeads: which one is the most effective? J Appl Oral Sci. 2019;27:e20180051.

38. Tembhurkar AR, Dongre S. Studies on fluoride removal using adsorption process. J Environ Sci Eng. 2006;48:151-156.

39. Janardhana C, Rao GN, Ramamurthy SS, Kumar PS, Kumar VA, Miriyala VM. Study on defluoridation of drinking water using zirconium ion impregnated. Indian J Chem Technol. 2007;14:350-354.

40. Brooks JK, Bashirelahi N, Reynolds MA. Charcoal and charcoal-based dentifrices: a literature review. J Am Dent Assoc. 2017;148:661-670.

41. Pertiwi UI, Eriwati YK, Irawan B. Surface changes of enamel after brushing with charcoal toothpaste. J Phys Conf Ser. 2017:884.

42. Franco MC, Uehara JLS, Meroni BM, Zuttion GS, Cenci MS. The Effect of a Charcoal-based Powder for Enamel Dental Bleaching. Oper Dent. 2020;45:618-623.

43. Aydın N, Karaoğlanoğlu S, Oktay EA, Ersöz B. Determination of the Whitening Effect of Toothpastes on Human Teeth. Odovtos-Int J Dent Sci. 2021;24:67-75.1;322-330.

44. Sulaiman TA, Camino RN, Cook R, Delgado AJ, Roulet JF, Clark WA. Time-lasting ceramic stains and glaze: A toothbrush simulation study. J Esthet Restor Dent. 2020;32:581-585.

45. Aydın N, Karaoğlanoğlu S, Oktay EA, Kılıçarslan MA. Investigating the color changes on resin-based CAD/CAM Block. J Esthet Restor Dent. 2020;32:251-256.

46. Koc Vural U, Bagdatli Z, Yilmaz AE, Yalçın Çakır F, Altundaşar E, Gurgan S. Effects of charcoal-based whitening toothpastes on human enamel in terms of color, surface roughness, and microhardness: an in vitro study. Clin Oral Investig. 2021;25:5977-5985.

47. Torso VH, Fraga MAA, Lopes RM, Aranha ACC, Correr-Sobrinho L, Correr AB. Charcoal-based dentifrices: Effect on color stability and surface wear of resin composites. J Esthet Restor Dent. 2021;33:815-823.

48. Dionysopoulos D, Papageorgiou S, Malletzidou L, Gerasimidou O, Tolidis K. Effect of novel charcoal-containing whitening toothpaste and mouthwash on color change and surface morphology of enamel. J Conserv Dent. 2021;23:624-631.

49. Palandi SDS, Kury M, Picolo MZD, Coelho CSS, Cavalli V. Effects of activated charcoal powder combined with toothpastes on enamel color change and surface properties. J Esthet Restor Dent. 2020;32:783-790.