REVIEW ARTICLE

Tooth-Bleaching: A Review of the Efficacy and Adverse Effects of Various Tooth Whitening Products

Abdul Majeed[1], Imran Farooq[2], Sias R. Grobler[3] and RJ Rossouw[3]

ABSTRACT

Tooth bleaching (whitening) is one of the most common and inexpensive method for treating discolouration of teeth. Dental aesthetics, especially tooth colour, is of great importance to majority of the people; and discolouration of even a single tooth can negatively influence the quality of life. Therefore, a review of the literature was carried out (limited to aesthetic tooth-bleaching) to provide a broad overview of the efficacy and adverse effects of various tooth whitening products on soft and hard oral tissues.

Key Words: *Tooth bleaching. Whitening. Peroxide. Discolouration.*

INTRODUCTION

Dental aesthetics, including tooth colour, is of great importance for majority of the people and any discolouration or staining can impact their quality of life negatively. The colour of teeth reflects a combination of its intrinsic colour and the presence of extrinsic stains due to various factors such as smoking, intake of tannin-rich foods and drinks (e.g. red wine), and the use of chlorhexidine or metal salts such as tin and iron.[1-3] A number of methods can be used to remove staining like professional cleaning and polishing, whitening tooth-pastes, internal bleaching of non-vital teeth, external bleaching of vital teeth, and micro-abrasion of enamel. Severe stains can be covered with crowns or veneers, but this is a more invasive and costly option.[4,5]

The increasing demand for a better appearance and whiter smile, has made vital tooth-bleaching (also referred to as tooth-whitening) a popular dental procedure. It has developed into one of the fastest growing areas of aesthetic dentistry. It provides a more conservative treatment approach for discoloured teeth as compared to other restorative treatment modalities such as composite fillings, veneers or crowns.[1] Commonly used methods for tooth-whitening include in-office or power bleaching,[6] dentist-supervised home bleaching or nightguard vital bleaching,[7] and easily available over-the-counter (OTC) whitening products for self-application.

[1] *Department of Restorative Dental Sciences / Biomedical Dental Sciences[2], College of Dentistry, University of Dammam, Saudi Arabia.*

[3] *Oral and Dental Research Institute, Faculty of Dentistry, University of Western Cape, South Africa.*

Correspondence: Dr. Imran Farooq, Department of Biomedical Dental Sciences, College of Dentistry, University of Dammam, Saudi Arabia.
E-mail: drimranfarooq@gmail.com

Received: December 10, 2014; Accepted: September 03, 2015.

METHODOLOGY

This literature review was limited to aesthetic tooth-bleaching and aimed to provide a broad overview of bleaching techniques, their efficacy, and adverse effects on soft and hard tissues as well as the management of tooth sensitivity and gingival irritation. In formulating this review, only English-language articles available electronically were selected. The PubMed database and Google scholar search engine were explored with keywords which included: tooth-whitening, tooth-bleaching, carbamide peroxide, hydrogen peroxide, bleaching and dentistry, home-bleaching, and vital bleaching. Over 200 articles were initially reviewed and 82 articles were shortlisted on the basis of their applicability to the present topic of review and then studied in detail.

Efficacy of different types of tooth-whitening products: Nightguard vital bleaching using 10% CP is the most widely used and extensively researched tooth-bleaching technique. The American Dental Association has awarded its seal of acceptance to a number of dentist-supervised home bleaching products containing 10% CP.[8] Nightguard vital bleaching techniques have been effective for bleaching teeth stained by aging, mild fluorosis, trauma, inherent discoloration and tetracycline.[9,10] According to the American Dental Association guidelines for the acceptance of peroxide-containing oral hygiene products, the clinical efficacy may be demonstrated by a change of two value oriented shade increments and a perceptible colour must be maintained in 50% of the recall population at 6 months compared to the control, to reflect the duration of efficacy.[11] In a long-term clinical trial, Leonard *et al*.,[12] reported whitening of teeth in 98% of the participants by 10% CP and 82% of the participants retained the whitening effect upto 47 months post-treatment. A meta-analysis of the clinical trials from 1989-1999 on dentist-supervised home bleaching products using 10% CP

suggested that only 73% of the population will show a colour change of two units or greater and 50% retain colour at 6 months postbleaching.[13] Higher CP concentrations (15% and 20%) available for home-bleaching may whiten teeth slightly quicker than 10% CP during the early phase of treatment. However, the whitening effect shows some relapse after the cessation of active bleaching treatment before the colour is stabilized. Teeth treated with 10% CP, stabilize in colour for 2 weeks following the cessation of the treatment but the higher-concentration products last much longer.[14] However, it is claimed that rapid whitening shown by the higher-concentration products is temporary and following rebound, there will be no difference.[15]

HP and CP tooth-bleaching products with equivalent peroxide concentrations demonstrate similar whitening efficacy with few side effects.[16,17]

A large number of OTC whitening products, including whitening strips or tray less whitening systems, paint-on-gels, gels with pre-fabricated trays and whitening toothpastes, have become increasingly popular in recent years because of their low cost to the consumer, and overwhelming marketing by manufacturing companies. Whitening strips usually contain 6 - 14% HP in gel form. An integrated clinical summary of nine randomized clinical trials reported the efficacy of whitening strips containing 14% HP similar to popular tray-based bleaching systems.[18] A clinical comparison of two brush-applied whitening systems showed that a 19% sodium percarbonate system, that dries to form an adherent film, provided significant improvement in tooth colour compared to 18% CP gel.[19] Zantner *et al*.[20] reported that a new bleaching lacquer, containing 8% CP for self-application without the use of a mouth guard, produced two shade improvements in tooth colour.

A recent systematic review[8] of home-based chemically-induced whitening of teeth demonstrated that dentist-supervised home bleaching systems and OTC products (paint-on gels and whitening strips) are effective when compared with placebo or no treatment and the efficacy varies because of different levels of active ingredients. However, the majority of the studies are either sponsored or conducted by the manufacturers and are of shorter term.[8] Furthermore, tooth-whitening products are not regulated in many countries and most of these products have not undergone clinical evaluation for safety and effectiveness. Therefore, there is a great need for independent laboratory and clinical trials which could provide a good indication of what could be expected in practice.

In-office bleaching procedures are performed using higher HP (30 - 38%) concentrations at chair-side under the close supervision of a dentist. A number of clinical studies have demonstrated the effectiveness of in-office bleaching alone[21-23] or in combination with further use of take-home bleaching products.[24,25] Auschill *et al*.,[26] in a randomized clinical trial comparing the efficacy of at-home, OTC and in-office bleaching techniques, reported that all treatment methods were able to achieve six grades of whitening but the time factor involved in the treatment was significantly different with the in-office bleaching technique requiring the least time. However, the most accepted method amongst the patients was the at-home bleaching technique. In contrast to these results, another study showed that treatment with an in-office bleaching (35% HP) product was less effective compared to a 14-day application of 10% CP in a tray.[27]

Special lights and heat-generation devices are also marketed by several companies as a necessary tool for in-office bleaching to expedite the bleaching efficacy. A few studies have reported the acceleration or enhancing effect of different light or laser sources on in-office bleaching treatments,[28-30] while other studies reported no effect of light-activation on the final outcome of in-office bleaching with HP.[31,32] Hein *et al*.,[33] investigated the contribution of three bleaching lights (Luma Arch, Optilux 500, and Zoom!) to act as catalysts for whitening teeth in a split-arch clinical study. He reported that neither the heat produced by the lights nor the light outputs per se were responsible for catalytic activity and the tested lights did not lighten teeth more than their irrespective bleaching gels alone. Inspite of contradictory reports in the literature, to-date there is no concrete evidence to show that these devices improve the final outcome of in-office bleaching treatment.[34,35]

In-office bleaching products are accepted by the American Dental Association but due to the discontinuation of the professional component of the Seal Program on December 31, 2007, these bleaching products are not eligible for the ADA Seal.[36]

Adverse effects: Adverse effects of vital tooth bleaching procedures on hard and soft tissues of the oral cavity have been reported in the literature.[37] Tooth sensitivity and gingival or mucosal irritation are the most common side effects of vital tooth-bleaching. Other effects include minor orthodontic tooth movement, temporomandibular dysfunction due to long-term tray use, and sore throat.[38]

Tooth sensitivity: Tooth sensitivity occurs in two-third of the patients treated with home bleaching products. The majority (55%) may experience mild sensitivity whereas 10% experience moderate and only 4% may experience severe sensitivity.[37] Symptoms are noticed early in the treatment, usually after 2 - 3 days, and may persist 3 - 4 hours following removal of the tray and disappear shortly after the treatment ends.[39] The aetiology of tooth sensitivity following bleaching treatment is multifactorial and is poorly understood.[40] Sensitivity is thought to be caused by the diffusion of by-products produced during HP and CP breakdown through dentinal tubules.[41]

Glycerine, used as a carrier in most bleaching agents, is hydrophilic and causes dehydration of tooth structure during bleaching treatment. This can also result in tooth sensitivity.[42] The use of bleaching products with higher peroxide concentration also increases the risk of tooth sensitivity.[43]

Patients with existing sensitivity should be treated before starting bleaching treatment: Desensitizing toothpastes and fluoride gels can be used for 2 - 3 weeks prior to the treatment or during treatment. A neutral sodium fluoride gel in a tray can be worn overnight or gels containing 3% to 5% potassium nitrate or fluoride and potassium nitrate in a tray before or after bleaching for 10 - 30 minutes. Furthermore, the frequency and / or duration of application can be reduced and the treatment can also be interrupted, if necessary.

Gingival or mucosal irritation: Some patients may experience gingival or mucosal irritation during home bleaching procedures. Soft tissue irritation may be caused by an ill-fitting tray impinging on the gingiva and/or the use of excess material.[39] Management includes simply adjusting and polishing the tray and or instructing the patient to use less material. During an in-office bleaching procedure, a higher HP concentration is usually used. HP is a caustic substance and can cause burns of the gingival or mucosal tissue.[44] Therefore, a rubber dam or light-cured resin, provided by the manufacturer, should always be used to protect soft tissues during in-office bleaching procedures.

Effects on tooth structure: Bleaching of vital teeth involves direct contact with the enamel surface for an extensive period of time which differs according to products. This fact increased concerns about the possible adverse effects of such a strong oxidizing agent on the enamel or dentine. The available literature is contradictory. Some scanning electron microscope studies reported changes in surface morphology of enamel following bleaching with CP[45,46] and/or HP products[47] while others reported no alterations in the enamel morphology.[48,49] Hegedüs *et al*.,[50] in an atomic force microscopy study, demonstrated that CP and HP were capable of causing alterations in enamel surface.

In a recent study,[51] it was found that all four different kinds of opalescence teeth whiteners damaged enamel. The most damage was done by the 10% and 20% CP products because of the much longer exposure period of 112 hours in comparison to only 7 hours for the Opalescence Quick PF 45% CP and Treswhite Supreme 10% HP. Certain studies have also reported negative effects on enamel and dentine microhardness,[52-56] while others reported no change in the microhardness of enamel[57,58] and dentine.[59] Lewinstein *et al*.[60] reported that in-office bleaching products, i.e. 35% HP and 35% CP, reduced hardness of enamel and dentine significantly more than the home bleaching products, i.e. 10% CP, but the application of 0.05% fluoride solution for 5 minutes completely restored the softened tooth structure. In an *in vitro* study, Sulieman *et al*.[61] reported that 35% HP did not damage enamel or dentine and the adverse effects reported in the literature may be related to the pH of the products used. A small reduction in dentine surface microhardness following exposure to 10% CP *in situ* was reported by Arcari *et al*.,[62] but they concluded that this might be clinically insignificant.

Current literature indicates that the experiments vary greatly in their methodology, the type of bleaching agent used, the duration of application, load applied and the position of indents. However, human enamel exhibits large regional variations in structure related to the differences in local chemistry (varying levels of mineralization, organic matter and water) and microstructure (fractions of inorganic crystals and organic matrix).[63,64] Therefore, enamel microhardness may vary from area to area. This may be the reason for controversies found in the literature. There is a great need to develop a standardized protocol to evaluate the effects of tooth-bleaching products on microhardness of enamel and dentine.

Effects on restorative materials: Increasing use of peroxide bleaching agents has raised concerns about their effects on different restorative materials. Several *in vitro* studies have evaluated the effects of CP (10 - 16%) and HP (30 - 35%) whitening products on the physical properties, surface morphology and colour of different restorative materials.[65] Haywood[66] reported that a nightguard vital bleaching technique had no significant effect on the colour and physical properties of porcelain, amalgam and gold. An increase in the surface roughness of porcelain, microfilled composite and modified glass ionomer following treatment with 10-16% CP was reported by Turker and Biskin.[67] Modified glass ionomer also showed increased surface porosity and cracks in certain areas. Controversy exists about the influence of external pre- and post-operative bleaching on microleakage of composite restorations. Crim[68] reported that pre-restorative bleaching with 10% CP did not affect the marginal seal of subsequently placed restorations. Ulukapi *et al*.[69] reported that pre- and post-operative bleaching with CP increased marginal leakage of resin composite restorations at enamel and dentine margins but amalgam restorations showed no alterations. In contrast, other studies did not report increased microleakage rate at enamel margins.[70]

The oxidation of surface pigments and amine compounds by bleaching agents can alter the colour of restorative materials. The oxidizing effect on the polymer-matrix of resin-based materials also increases surface porosities.[64] There is no clear evidence indicating whether the changes in tooth-coloured restorative

materials are superficial or deep. However, polishing of resin composite fillings is advisable following bleaching procedures to decrease the adherence of certain cariogenic micro-organisms.

Bleaching agents also cause increased release of mercury from amalgam restorations.[71] Coating of amalgam restorations with a protective varnish such as Copalite before bleaching procedure has been reported to reduce release of mercury into the surrounding environment.[72] The corrosion potential of amalgam is also decreased if restorations are polished prior to the bleaching therapy.

Effects on bond strength: The effect of various bleaching procedures on shear or tensile bond strength of composites to enamel and dentine has been studied extensively. The majority of the studies reported that the bond strengths of composite restorative materials to enamel and dentine[73-76] was significantly reduced when applied immediately after bleaching with HP or CP. Josey *et al*.[77] reported no negative effects of 10% CP bleaching on composite-enamel bond strength. However, controversy exists about the effects of alcohol- or acetone-based bonding agents on the bond strengths to enamel and dentine.[64]

Several factors are responsible for the reduction in composite bond strengths to enamel and dentine. Polymerization inhibition of the resin adhesive systems, due to the presence of oxygen released by the bleaching process on the enamel surface and within the dentinal tubules, is the likely mechanism for the reduction in bond strength.[78] Significant loss of enamel calcium and phosphorus content and morphological alterations of the majority of the crystals of the surface layer caused by the peroxide-based bleaching agents also adversely affects the bond strength.[79] Adebayo *et al*.,[80] reported that the use of conditioners prior to bonding with self etching adhesive system to bleached enamel may significantly improve bond strength. However, the reduction in bond strength is time-dependent and returns to normal after a few days, when the residual oxygen is liberated. Recommended waiting time before performing bonding procedures after tooth bleaching ranges from 3 to 7 days,[81] 7 - 14 days[78] to 3 weeks.[82] Therefore, it is advisable to wait for a while before performing bonding procedures after bleaching.

CONCLUSION

Different treatment modalities are available to the patient designing a whiter smile. Tooth sensitivity and gingival or mucosal irritation are the most common side effects of vital tooth-bleaching. However, ADA recognised products tend to include agents to minimize or prevent these side effects. Dentists should educate themselves to be able to inform their patients about the benefits and risks of different whitening methods based on the current scientific evidence and to suggest the best treatment option based on a correct diagnosis.

REFERENCES

1. Kihn PW. Vital tooth whitening. *Dent Clin N Am* 2007; **51**: 319-31.
2. Watts A, Addy M. Tooth discolouration and staining: a review of the literature. *Br Dent J* 2001; **190**:309-16.
3. Nathoo S. The chemistry and mechanisms of extrinsic and intrinsic discoloration. *J Am Dent Assoc* 1997; **128** (Suppl):6S-10S.
4. Joiner A. The bleaching of teeth: a review of the literature. *J Dent* 2006; **34**:412-9.
5. Sarrett DC. Tooth whitening today. *J Am Dent Assoc* 2002; **133**:1535-8.
6. Zantner C, Beheim-Schwarzbach N, Neumann K, Kielbassa AM. Surface microhardness of enamel after different home bleaching procedures. *Dent Mater* 2007; **23**:243-50.
7. Haywood VB, Heymann HO. Nightguard vital bleaching. *Quintessence Int* 1989; **20**:173-6.
8. Hasson H, Ismail AI, Neiva G. Home-based chemically-induced whitening of teeth in adults. *Cochrane Datab Syst Rev* 2006, Issue 4. Art. No.: CD006202. DOI: 10.1002/14651858.CD006202.
9. Sulieman M. An overview of bleaching techniques: 3. In-surgery or power bleaching. *Dent Update* 2005; **32**:101-8.
10. Haywood VB, Leonard RH, Nelson CF, Brunson WD. Effectiveness, side effects and long-term status of nightguard vital bleaching. *J Am Dent Assoc* 1994; **125**:1219-26.
11. American Dental Association. Guidelines for the acceptance of peroxide-containing oral hygiene products. *J Am Dent Assoc* 1994; **125**:1140-2.
12. Leonard RH Jr, Bentley C, Eagle JC, Garland GE, Knight MC, Phillips C. Nightguard vital bleaching: a long-term study on efficacy, shade retention, side effects, and patients' perceptions. *J Esthet Restor Dent* 2001; **13**:357-69.
13. Niederman R, Tantraphol MC, Slinin P, Hayes C, Conway S. Effectiveness of dentist-prescribed, home-applied tooth whitening. A meta-analysis. *J Contemp Dent Prac* 2000; **1**:1-16.
14. Matis BA, Mousa HN, Cochran MA, Eckert GJ. Clinical evaluation of bleaching agents of different concentrations. *Quintessence Int* 2000; **31**:303-10.
15. Browning WD. Critical appraisal. Comparison of the effectiveness and safety of CP whitening agents at different concentrations. *J Esthet Restor Dent* 2007; **19**:289-96.
16. Ziebolz D, Helms K, Hannig C, Attin T. Efficacy and oral side effects of two highly concentrated tray-based bleaching systems. *Clin Oral Invest* 2007; **11**:267-75.
17. Berga-Caballero A, Forner-Navarro L, Amengual-Lorenzo J. At-home vital bleaching: a comparison of HP and CP treatments. *Med Oral Patol Oral Cir Bucal* 2006; **11**:E94-9.
18. Gerlach RW, Barker ML. Professional vital bleaching using a thin and concentrated peroxide gel on whitening strips: an integrated clinical summary. *J Contemp Dent Pract* 2004; **5**: 001-17.
19. Barlow A, Gerlach RW, Date RF, Brennan K, Struzycka I, Kwiatkowska A, *et al.* Clinical response of two brush-applied peroxide whitening systems. *J Clin Dent* 2003; **14**: 59-63.

20. Zantner C, Derdilopoulou F, Martus P, Kielbassa AM. Randomized clinical trial on the efficacy of a new bleaching lacquer for self-application. *Oper Dent* 2006; **31**:308-16.

21. Matis BA, Cochran MA, Franco M, Al-Ammar W, Eckert GJ, Stropes M. Eight in-office tooth whitening systems evaluated *in vivo*: A pilot study. *Oper Dent* 2007; **32**:322-7.

22. Al Shethri S, Matis BA, Cochran MA, Zekonis R, Stropes M. A clinical evaluation of two in-office bleaching products. *Oper Dent* 2003; **28**:488-95.

23. Gallagher A, Maggio B, Bowman J, Borden L, Mason S, Felix H. Clinical study to compare two in-office (chairside) whitening systems. *J Clin Dent* 2002; **13**:219-24.

24. Wetter NU, Branco EP, Deana AM, Pelino JE. Color differences of canines and incisors in a comparative long-term clinical trial of three bleaching systems. *Lasers Med Sci* 2008; **22**.

25. Deliperi S, Bardwell DN, Papathanasiou A. Clinical evaluation of a combined in-office and take-home bleaching system. *J Am Dent Assoc* 2004; **135**:628-34.

26. Auschill TM, Hellwig E, Schmidale S, Seulean A, Arweiler NB. Efficacy, side-effects and patients' acceptance of different bleaching techniques (OTC, in-office, at-home). *Oper Dent* 2005; **30**:156-63.

27. Zekonis R, Matis BA, Cochran MA, Al Shetri SE, Eckert GJ, Carlson TJ. Clinical evaluation of in-office and at-Home bleaching treatments. *Oper Dent* 2003; **28**:114-21.

28. Luk K, Tam L, Hubert M. Effect of light energy on peroxide tooth bleaching. *J Am Dent Assoc* 2004; **135**:194-201.

29. Tavares M, Stultz J, Newman M, Smith V, Kent R, Carpino E, *et al.* Light augments tooth whitening with peroxide. *J Am Dent Assoc* 2003; **134**:167-75.

30. Nakamura T, Saito O, Ko T, Maruyama T. The effects of polishing and bleaching on the colour of discoloured teeth *in vivo*. *J Oral Rehabil* 2001, **28**:1080-4.

31. Marson FC, Sensi LG, Vieira LCC, Araújo E. Clinical evaluation of in-office dental bleaching treatments with and without the use of light-activation sources. *Oper Dent* 2008; **33**:15-22.

32. Kugel G, Papathanasiou A, Williams AJ 3rd, Anderson C, Ferreira S. Clinical evaluation of chemical and light-activated tooth whitening systems. *Compend Contin Educ Dent* 2006; **27**:54-62.

33. Hein DK, Ploeger BJ, Hartup JK, Wagstaff RS, Palmer TM, Hansen LD. In-office vital tooth bleaching--what do lights add? *Compend Contin Educ Dent* 2003; **24**:340-52.

34. Ritter AV. Talking with patients. In-office tooth bleaching. *J Esthet Restor Dent* 2006; **18**:168-9.

35. Papathanasiou A, Kastali S, Perry RD, Kugel G. Clinical evaluation of a 35% HP in-office whitening system. *Compend Contin Educ Dent* 2002; **23**:335-8.

36. American Dental Association. ADA statement on the safety and effectiveness of tooth whitening products. www.ada.org/prof/resources/positions/statements/whiten2.asp (accessed September 2008).

37. Jorgensen MG, Carroll WB. Incidence of tooth sensitivity after home whitening treatment. *J Am Dent Assoc* 2002; **133**:1076-82.

38. Pohjola RM, Browning WD, Hackman ST, Myers ML, Downey MC. Sensitivity and tooth whitening agents. *J Esthet Restor Dent* 2002; **14**:85-91.

39. Sulieman M. An overview of bleaching techniques: 2. nightguard vital bleaching and non-vital bleaching. *Dent Update* 2005; **32**:39-46.

40. Perdigao J, Baratieri LN, Arcari GM. Contemporary trends and techniques in tooth whitening: a review. *Pract Proced Aesthet Dent* 2004; **16**:185-92.

41. Gokay O, Tuncbilek M, Ertan R. Penetration of the pulp chamber by CP bleaching agents on teeth restored with a composite resin. *J Oral Rehabil* 2000; **27**:428-31.

42. Leonard RH, Haywood VB, Phillips C. Risk factors for developing tooth sensitivity and gingival irritation associated with nightguard vital bleaching. *Quintessence Int* 1997; **28**: 527-34.

43. Jacobsen PL, Bruce G. Clinical dentine hypersensitivity: understanding the causes and prescribing a treatment. *J Contemp Dent Pract* 2001; **2**:1-8.

44. Pretty IA, Ellwood RP, Brunton PA, Aminian A. Vital tooth bleaching in dental practice: 1. Professional bleaching. *Dent Update* 2006; **33**:288-300.

45. Pinto CF, Oliveira R, Cavalli V, Giannini M. Peroxide bleaching agent effects on enamel surface microhardness, roughness and morphology. *Braz Oral Res* 2004; **18**:306-11.

46. Smidt A, Weller D, Roman I. Effect of bleaching agents on microhardness and surface morphology of tooth enamel. *Am J Dent* 1998; **11**:83-5.

47. Ernst CP, Morroquin BB, Willershausen-Zonnchen B. Effects of HP-containing bleaching agents on the morphology of human enamel. *Quintessence Int* 1996; **27**:53-6.

48. Haywood VB, Houck VM, Heymann HO. Nightguard vital bleaching: effects of various solutions on enamel surface texture and color. *Quintessence Int* 1991; **22**:775-82.

49. Haywood VB, Leech T, Heymann HO, Crumpler D, Bruggers K. Nightguard vital bleaching: effects on enamel surface texture and diffusion. *Quintessence Int* 1990; **21**:801-4.

50. Hegedüs C, Bistey T, Flora-Nagy E, Kesthelyi G, Jenei A. An atomic force microscopy study on the effect of bleaching agents on enamel surface. *J Dent* 1999; **27**:509-15.

51. Majeed A, Grobler SR, Moola MH, Rossouw RJ, van Wyk-Kotze TJ. Effect of four different opalescence tooth-whitening products on enamel microhardness. *S Afr Dent J* 2008; **63**: 282-6.

52. Ulukapi H. Effect of different bleaching techniques on enamel surface microhardness. *Quintessence Int* 2007; **38**:358,e201-5.

53. Rodrigues JA, Marchi GM, Ambrosano GMB, Heymann HO, Pimenta LA. Microhardness evaluation of *in situ* vital bleaching on human dental enamel using a novel study design. *Dent Mater* 2005; **21**:1059-67.

54. Basting RT, Rodrigues Jr AL, Serra MC. The effect of seven CP bleaching agents on enamel microhardness over time. *J Am Dent Assoc* 2003; **134**:1335-42.

55. Dadoun MP, Bartlett DW. The microhardness of bleached dentine and its bond strength to a dentine bonding agent. *Eur J Prosthodont Restor Dent* 2007; **15**:131-4.

56. Basting RT, Rodrigues AL Jr, Serra MC. The effect of 10% CP, carbopol and/or glycerin on enamel and dentin microhardness. *Oper Dent* 2005; **30**:608-16.

57. Ferreira IA, Lopes GC, Cardoso Vieira LC, Araujo E. Effect of

hydrogen-peroxide-based home bleaching agents on enamel hardness. *Braz J Oral Sci* 2006; **5**:1090-3.

58. Seghi RR, Denry I. Effects of external bleaching on indentation and abrasion characteristics of human enamel *in vitro*. *J Dent Res* 1992; **71**:1340-44.
59. Ünlü N, Cobankara FK, Altinöz C, Özer F. Effect of home bleaching agents on the microhardness of human enamel and dentine. *J Oral Rehabil* 2004; **31**:57-61.
60. Lewinstein I, Fuhrer N, Churaru N, Cardash H. Effect of different peroxide bleaching regimens and subsequent fluoridation on the hardness of human enamel and dentine. *J Prosthet Dent* 2004; **92**:337-42.
61. Sulieman M, Addy M, Macdonald E, Rees JS. A safety study *in vitro* for the effects of an in-office bleaching system on the integrity of enamel and dentine. *J Dent* 2004; **32**:581-90.
62. Arcari GM, Baratieri LN, Maia HP, De Freitas SF. Influence of the duration of treatment using 10% CP bleaching gel on dentin surface microhardness: an *in situ* study. *Quintessence Int* 2005; **36**:15-24.
63. Braly A, Darnell LA, Mann AB, Teaford MF, Weihs TP. The effect of prism orientation on the indentation testing of human molar enamel. *Arch Oral Biol* 2007; **52**:856-60.
64. Spalding M, Taveira LA, de Assis GF. Scanning electron microscopy study of dental enamel surface exposed to 35% HP: alone, with saliva, and with 10% CP. *J Esthet Restor Dent* 2003; **15**:154-65.
65. Attin T, Vollmer D, Wiegand A, Attin R, Betke H. Subsurface microhardness of enamel and dentin after different external bleaching procedures. *Am J Dent* 2005; **18**:8-12.
66. Haywood VB. History, safety and effectiveness of current bleaching techniques and application of the night guard vital bleaching technique. *Quintessence Int* 1992; **27**:471-88.
67. Turker SB, Biskin T. Effect of three bleaching agents on the surface properties of three different esthetic restorative materials. *J Prosthet Dent* 2003; **89**:466-73.
68. Crim GA. Pre-restorative bleaching: effect on microleakage of Class V cavities. *Quintessence Int* 1992; **23**:823-5.
69. Ulukapi H, Benderli Y, Ulukapi I. Effect of pre- and postoperative bleaching on marginal leakage of amalgam and composite restorations. *Quintessence Int* 2003; **34**:505-8.
70. Owens BM, Rowland CC, Brown DM, Covington JS 3rd. Postoperative dental bleaching: effect of microleakage on Class V tooth colored restorative materials. *J Tenn Dent Assoc* 1998; **78**:36-40.
71. Rotstein I, Avron Y, Shemesh H, Dogan H, Mor C, Steinberg D. Factors affecting mercury release from dental amalgam exposed to CP bleaching agent. *Am J Dent* 2004; **17**:347-50.
72. Rotstein I, Dogan H, Avron Y, Shemesh H, Mor C, Steinberg D. Protective effect of Copalite surface coating on mercury release from dental amalgam following treatment with CP. *Endod Dent Traumatol* 2000; **16**:107-10.
73. Shinohara MS, Peris AR, Pimenta LA, Ambrosano GM. Shear bond strength evaluation of composite resin on enamel and dentin after non-vital bleaching. *J Esthet Restor Dent* 2005; **17**:22-9.
74. Sung EC, Chan SM, Mito R, Caputo AA. Effect of CP on the shear bond strength of composite to dental bonding agent enhanced enamel. *J Prosthet Dent* 1999; **82**:595-9.
75. Far C, Ruse ND. Effect of bleaching on fracture toughness of composite-dentin bonds. *J Adhes Dent* 2003; **5**:175-82.
76. Spyrides GM, Perdigão J, Pagani C, Araújo MA, Spyrides SM. Effect of whitening agents on dentin bonding. *J Esthet Dent* 2000; **12**:264-70.
77. Josey AL, Meyers IA, Romaniuk K, Symons AL. The effect of a vital bleaching technique on enamel surface morphology and the bonding of composite resin to enamel. *J Oral Rehabil* 1996; **23**:244-50.
78. Barbosa CM, Sasaki RT, Florio FM, Sasting RT. Influence of time on bond strength after bleaching with 35% HP. *J Contemp Dent Pract* 2008; **9**:081-8.
79. Perdigão J, Francci C, Swift EJ Jr, Ambrose WW, Lopes M. Ultra-morphological study of the interaction of dental adhesives with CP-bleached enamel. *Am J Dent* 1998; **11**: 291-301.
80. Adebayo OA, Burrow MF, Tyas MJ. Effects of conditioners on microshear bond strength to enamel after CP bleaching and/or casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) treatment. *J Dent* 2007; **35**:862-70.
81. McGuckin RS, Thurmond BA, Osovitz S. Enamel shear bond strengths after vital bleaching. *Am J Dent* 1992; **5**:216-22.
82. Cavalli V, Reis AF, Giannini M, Ambrosano GM. The effect of elapsed time following bleaching on enamel bond strength of resin composite. *Oper Dent* 2001; **26**:597-602.