Alterations in enamel surface morphology after using six bleaching products - A scanning electron microscope study

Wedad Y. Awliya*, BDS, MSc, Areej Al-Jaralla,** BDS
Arwa Al Abdul Qader,** BDS

الغرض من هذا البحث هو تحيل تأثير ثلاثة من أنظمة التبييض المستعملة في عيادة الأسنان (هيدروجين بيروكسايد ٣٥٪) ونوعين من أنواع التبييض المنزلي والذي يتم أيضا تحت الإشراف الطبي (كارباميد بيروكسايد ١٦٪ و ١٠٪) على ميناء الأسنان و ذلك باستعمال المجهر الالكتروني الماسح. تم قطع تيجان الأسنان الضواحك التي تم خلعها حديثا من ١١ شخصا إلى نصفين باستخدام منشار خاص مع التبريد بالماء. وجرى بعد ذلك تتعيم العينات بورق صنفرة خشن ورطب مصنوع من أو كسيد الألمونيوم مقاس ٦١٠٠ ، ١٠٠٠ ، و١٢٠٠٠. تم تقسيم العينات بعد ذلك عشوائيا إلى سبع مجموعات حسب نوعية مادة التبييض (عدد=٣) المجموعة الأولى التبييض في عيادة الأسنان تحت إشراف الطبيب ("أوبالسينس – إكسترا")، المجموعة الثانية و الثالثة التبييض المنزلي تحت إشراف طبي ("نايت وايت" و "بلينش ١٠")، والمجموعة الرابعة و الخامسة والسادسة التبييض بالمنتجات التجارية (جل "رابد وايت"، و "رابد وايت برش أون" الذي يعمل على خطوتين، والجل ناتشورال وايت) والمجموعة السابعة وضعت في لعاب مصنع كمجموعة مقارنة ايجابيه ، تم بعد ذلك القيام بإجراءات التبييض على سطوح ميناء الأسنان طبقا لتعليمات الشركات الصانعة. وبعد كل عملية تبييض كانت العينات تحفظ في لعاب مصنع. و جرى بعد الانتهاء من التبييض فحص العينات تحت المجهر الإليكتروني الماسح. وقد أظهرت النتائج أن جميع منتجات التبيض المستخدمة في هذا البحث سببت تغيرات في سطوح ميناء الأسنان. غير أن هذه التغييرات كانت مختلفة الحدة في كل مجموعة. حيث أن سطوح ميناء العينات التي أخضعت لهيدروجين البيروكسايد ٣٥٪ كانت الأكثر تأثرا يليها ميناء الأسنان التي خضعت للتبييض المنزلي تحت إشراف طبي (كارباميد البيروكسايد ١٦٪ و ١٠٪).

The purpose of this study was to analyze the effect of six bleaching products on enamel surface morphology using scanning electron microscope (SEM). The crowns of eleven human premolars recently extracted were sectioned mesiodistally using water-cooled slow speed diamond saw. Twenty-one dental fragments were divided into seven groups as per treatment modality (n = 3): Opalescence Xtra for office bleaching (35% hydrogen peroxide), two professional home bleaching products: Nite White (16% carbamide peroxide) and Bleach 10 (10% carbamide peroxide), three over the counter bleaching systems: Rapid White gel, Rapid White 2 Steps Brush On (non peroxide bleaching products) and Natural White gel (hydrogen peroxide concentration is not indicated). The seventh group was stored in artificial saliva to serve as control. The bleaching procedures were conducted on enamel surfaces according to manufacturer's instructions. The office bleaching procedure was conducted once weekly for two weeks and the other home bleaching procedures were conducted daily for two weeks. Following each bleaching session, the specimens were kept in artificial saliva. Control specimens were kept in artificial saliva for two weeks at 37 ^{O}C. After 2 weeks, the specimens were examined for surface changes with scanning electron microscope. The SEM showed enamel surface alterations on all surfaces treated with all the bleaching agents used in this study. However, enamel surfaces treated with 35% hydrogen peroxide showed the most significant changes with increase in surface pores and big areas of surface destruction. Surface alterations caused by the other products were not uniform, occurring with varying intensity.

INTRODUCTION

Esthetic dentistry, particularly tooth whitening, is one of the most rapidly growing treatment areas in dentistry.[1] The so-called "in-office" tooth bleaching technique requires the use of 30-35% hydrogen peroxide and direct monitoring by dentists.[2] At home, tooth bleaching or "night-guard" vital bleaching uses 10-20% carbamide peroxide in a custom-made mouth-guard worn at patient's convenience daily for several weeks.

Hydrogen peroxide diffuses through the organic matrix of enamel and dentin because of its low molecular weight.[3] Peroxide decomposes into free radicals that attack the organic molecule releasing other radicals. These radicals break down large pigmented molecules responsible

Received 28 May 2005; Revised 16 October 2005
Accepted 26 November 2005
*Associate Professor
Department of Restorative Dental Sciences
** Interns
College of Dentistry, King Saud University, Riyadh, KSA

Address reprint requests to:
Dr. Wedad Y. Awliya
College of Dentistry, King Saud University
P.O. Box 5967, Riyadh 11432, KSA
E-mail: wawliya@hotmail.com

for color stain in enamel into smaller less pigmented molecules.[4] The chemistry of carbamide peroxide used in at-home bleaching is thought to be a bit different from hydrogen peroxide, although the final stage involves reaction of hydrogen peroxide with the compounds within the tooth. A solution of carbamide peroxide breaks down into hydrogen peroxide and urea. Both hydrogen peroxide and urea access the internal tooth in minutes to remove discoloration and brighten the inherent color of the dentin itself.[5]

The reduced cost and convenient use of the professional at-home bleaching agents led to the introduction of over-the-counter (OTC) tooth whitening products. Some of these OTC products are tray-delivered systems. These systems must be used with caution because ready made ill-fitting trays can lead to soft tissue injury, malocclusion problems and poor compliance.[6,7] Some of these OTC products contain, among other ingredients, approximately 10% carbamide peroxide in anhydrous glycerol base.[8]

Despite the favorable results achieved with in-office and at-home bleaching products, some reports in the literature have indicated adverse side effects as a consequence of the treatment.[9,10] Sensitivity following the treatment has been related to the possible removal of mineral content from enamel and dentin.[9] Pinto et al.[10] found significant surface alterations in enamel topography following enamel bleaching with 10% carbamide peroxide. However, White et al.[11] showed no change in surface morphology of human enamel outside of normal variations using SEM.

The purpose of this study was to test the effect of one office bleaching gel (35% hydrogen peroxide), professional home bleaching gels (10% and 16% carbamide peroxide) and some OTC home tooth whitening products on enamel surface texture using scanning electron microscope (SEM).

MATERIALS AND METHODS

Specimens Preparation

Eleven non-carious, human premolar that were recently extracted for periodontal reasons, were immediately stored in saline at 37 ^{o}C. The teeth were submitted to soft-tissue debridement with periodontal curettes and cleaned with slurry of pumice using rubber cup in slow speed handpiece. The roots were removed approximately 2-3 mm apical to the cemento enamel junction. Then the crowns were sectioned mesiodistaly using water-cooled slow speed diamond saw. Twenty-one dental fragments from buccal and lingual (4 x 4 x 3 mm) enamel surfaces were obtained. The specimens were then randomly divided into seven groups each group containing three specimens. Enamel surfaces in each group were treated with one of bleaching products according to manufacturers' instructions. The bleaching materials tested in this study, their composition, and manufacturers are presented in Table 1.

Exposure of the Specimens to the Bleaching Agents

Specimens in the first group (in-office bleaching) were coated with Opalescence Xtra gel then they were exposed to a Heliolux light-curing unit* for 20 seconds. After 5 minutes, the activation was repeated. After 10 minutes cumulative activation, the gel was removed by suction only, and then the specimens were rinsed with deionized water and stored for 1 week in artificial saliva which had a composition shown in Table 2. The same procedure was repeated again after one week.

* Vivadent USA, Amherst, NY 14228, USA

Table 1. Bleaching materials used in the study and their composition.

Material	Composition
Opalescence Xtra, In office power Bleach Ultra Dent Products Inc. 505 West 10200 South, South Jordan, Utah 84095, USA	35% hydrogen peroxide powder bleaching Carotene (light absorbing heat-activated chemistry)
Bleach 10, Promedica Domagkstr.31.24537 Neumunster, Germany	10% carbamide peroxide potassium fluoride
Nite-White whitening-gel, Discus Dental 8550, Higuera Street Culver City, CA 90232, USA	16% carbamide peroxide, polyethylene glycol, propylene glycol, hydroxypolicelluos, carbopol, flavor, sodium hydroxide
Rapid White Natural White Inc, 175 Cooper Avenue, Tonawanda, NY 14150, USA	Gel: Water, glycerin, carbomer, 474 P, Aroma sodium hydroxide, citric acid methyl paraben Accelerator: Stabilized chlorine dioxide
Rapid White-Brush On Natural White Inc, 175 Cooper Avenue, Tonawanda, NY 14150,USA	Gel: Water, glycerin, carbomer, polsorbate 20, citric acid flavor, methyl paraben, sodium hydroxide Accelerator: water, sodium chlorite, xanthan gum, carrageenan, sodium benzoate, methylparaben, propylparaben
Natural White Natural White Inc, 175 cooper Avenue, Tonawanda, NY 14150, USA	Water, glycerin, carbomer 974P, hydrogen peroxide (concentration not indicated), ammonium hydroxide, sodium stannate Oral Rinse: Water, SD alcohol 38B, sorbitol, sodium bicarbonate, polaxamer 407, sodium saccharin, FD& C Blue #1

Table 2. Composition of the artificial saliva used in the study

NaCl	0.400 gm
KCl	0.400 gm
$CaCl_2H_2O$	0.795 gm
$NaH_2PO_4. H_2O$	0.69 gm
Na_2 S. 9H2O	0.005 gm
Distilled water	1000 ml

In the second and third groups (professional home bleaching) test specimens were coated with Bleach 10 and Nite White, for 4 hours daily for two weeks as recommended by the manufacturers. After each exposure, the specimens were rinsed with deionized water and stored in artificial saliva till the next exposure.

In the fourth and fifth groups, (Rapid White bleaching gel and Rapid White 2 Steps Brush On), the Rapid White accelerator was applied to the surface of the teeth followed by the whitening material. The gel and the brushing material were left on the teeth for 10 minutes and for 30 seconds, respectively. The specimens were then rinsed with deionized water and stored in artificial saliva. Natural White bleaching gel was placed on enamel surfaces in the sixth group for 15 minutes daily. After each exposure the teeth were rinsed first with deionized water then with the oral rinse included in the kit before their storage in artificial saliva. The application of all OTC home-bleaching gels to enamel samples was also, repeated daily for 15 days before testing. The seventh group served as control, no bleaching treatment was performed and the specimens were kept in artificial saliva for 15 days at 37^{O}C.

When the bleaching regimens were completed, the enamel of each specimen was desiccated and coated with approximately 500 µm of gold.** All specimens were then examined at 500X and 2000X magnifications with SEM.***

RESULTS

SEM analysis of the surfaces treated with the different bleaching systems showed different patterns. Figure 1 showed the surfaces of unbleached enamel (control). No alteration of enamel pattern was evident, however, scattered

** E5000 Polaron, Hatfield, PA, USA
***JSM, 6360 LV, JEOL Corp., Peabody, Massachusetts.

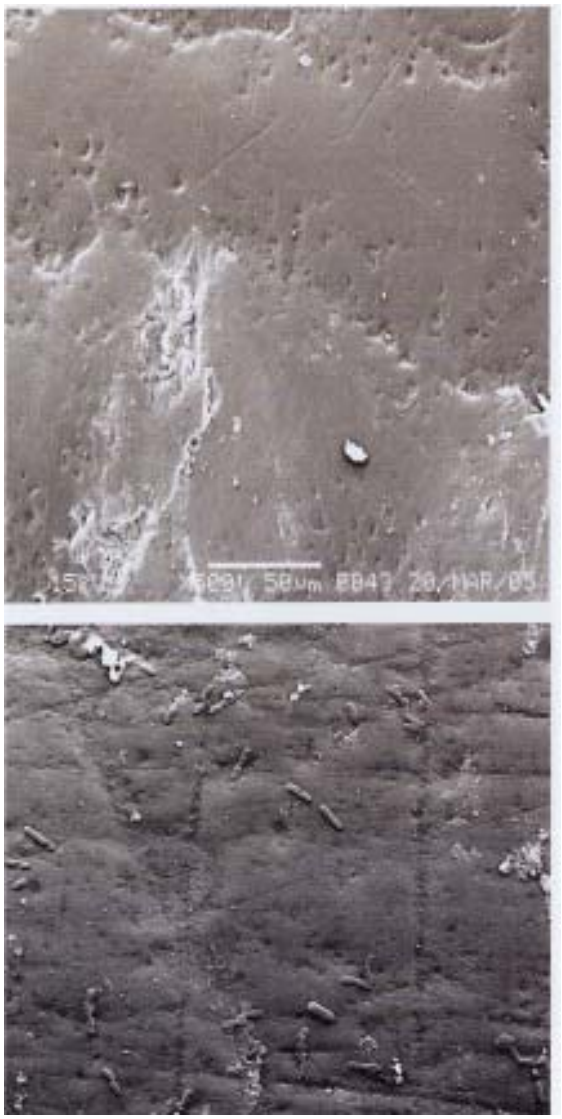

Fig. 1. SEM of enamel specimens stored in artificial saliva (Control) No alteration of enamel pattern was evident, scattered bacteria were seen on the surface.

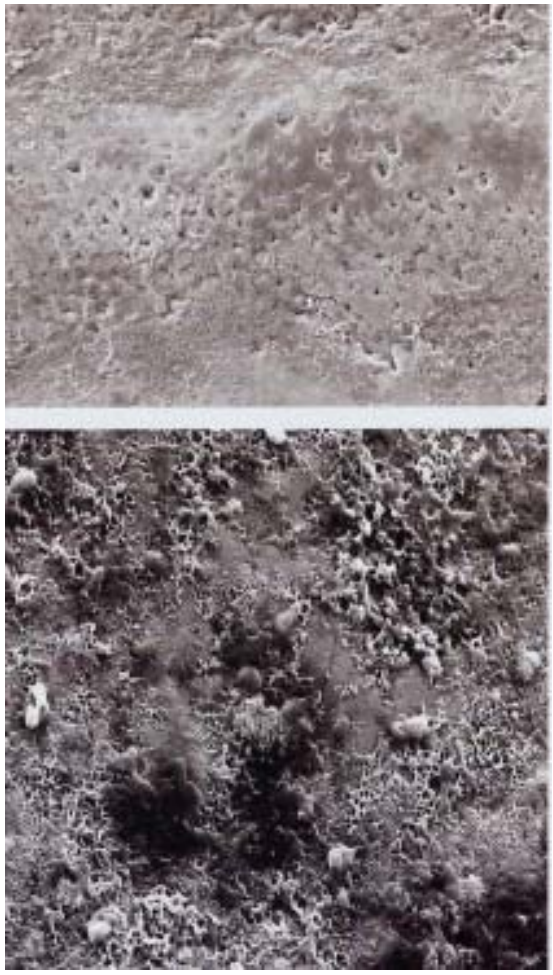

Fig. 2. SEM of enamel specimens treated with Opalescence Xtra (in-offi ce bleaching, 35% hydrogen peroxide). Big areas of enamel destruction and increase in surface porosity.

bacteria were seen on the surface. Enamel surfaces treated with Opalescence Xtra showed the most significant alteration. Big areas of enamel destruction, an increase in surface porosity and etching like appearance were seen (Fig. 2). Apparent increase in surface porosity was also, observed on surfaces treated with Nite White (Fig. 3) and Rapid White (Fig. 4). However, surfaces treated with Nite White showed presence of white shiny areas around the pores. On the other hand, at high magnification (2000x) Rapid white showed presence of round globules inside the pores. A precipitate was noted on the surface treated with Bleach 10 giving it a frosted appearance. The precipitate was so dense that it obscured the surface morphology of enamel (Fig. 5). Irregular pattern of enamel erosion was evident in specimens treated with Natural White, with less porosity than the previous systems and with some precipitate on the surface (Fig. 6). At lower magnification

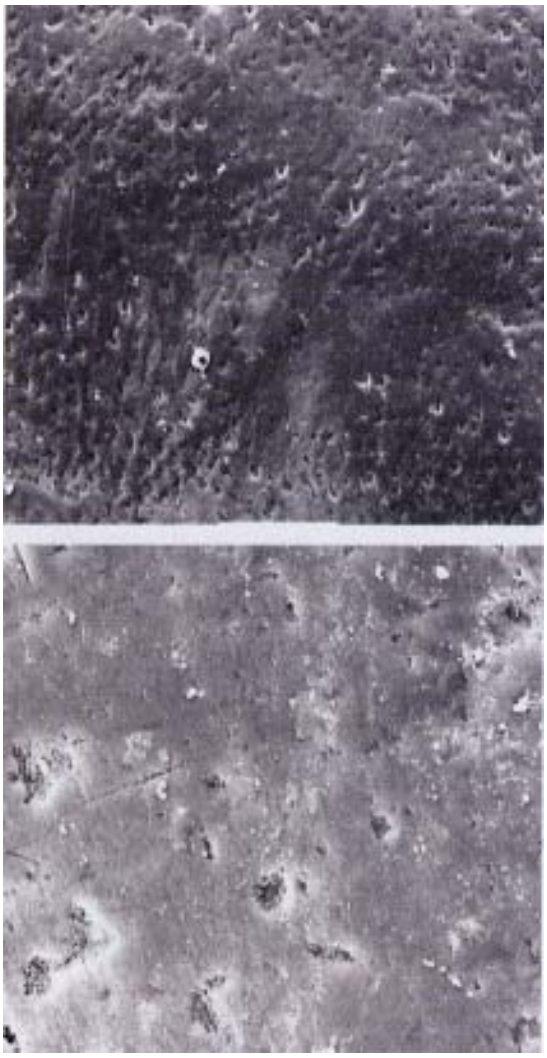

Fig. 3. SEM of enamel specimens treated with Nite White (home bleaching, 16% carbamide peroxide). Increase in surface porosity and presence of white shiny areas around the pores.

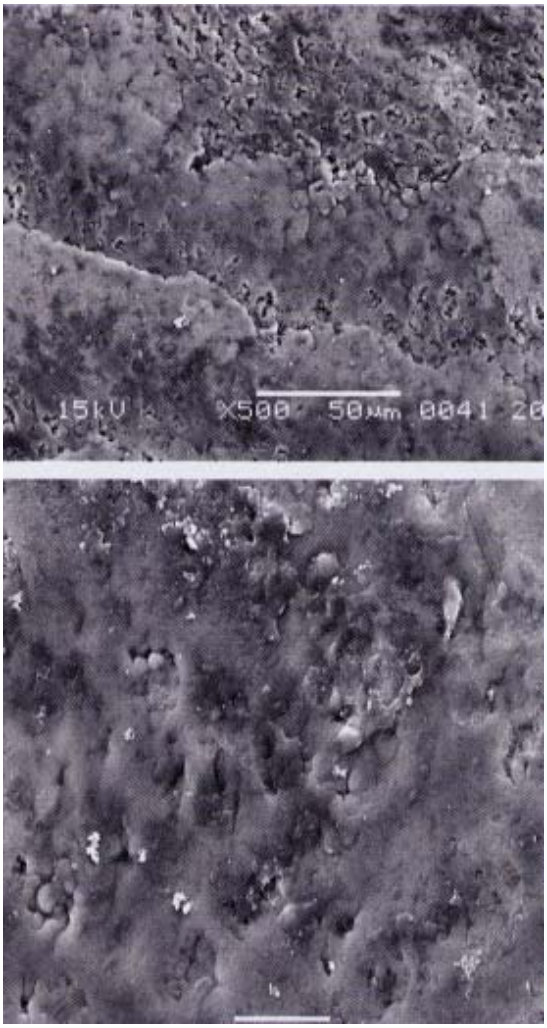

Fig. 4. SEM of enamel specimens treated with Rapid White (OTC home bleaching). Apparent increase in surface porosity

(500x) Rapid White Brush On bleaching system, showed the least changes in surface morphology. However, at higher magnification (2000x) enamel surface showed shallow depressions with some residual debris (Fig. 7).

DISCUSSION

Concern has been expressed regarding the effects of the bleaching products on enamel surfaces.[12] Although several scanning electron microscope studies have been conducted on enamel surfaces treated with different concentrations of carbamide peroxide, there is contradictory evidence of the negative effects on enamel surface morphology.[13,14] In this study enamel surfaces bleached with Opalescence Xtra caused the most significant alteration in enamel surfaces. The big areas of surface destruction and the apparent increase in surface porosity, caused by 35% hydrogen peroxide, were

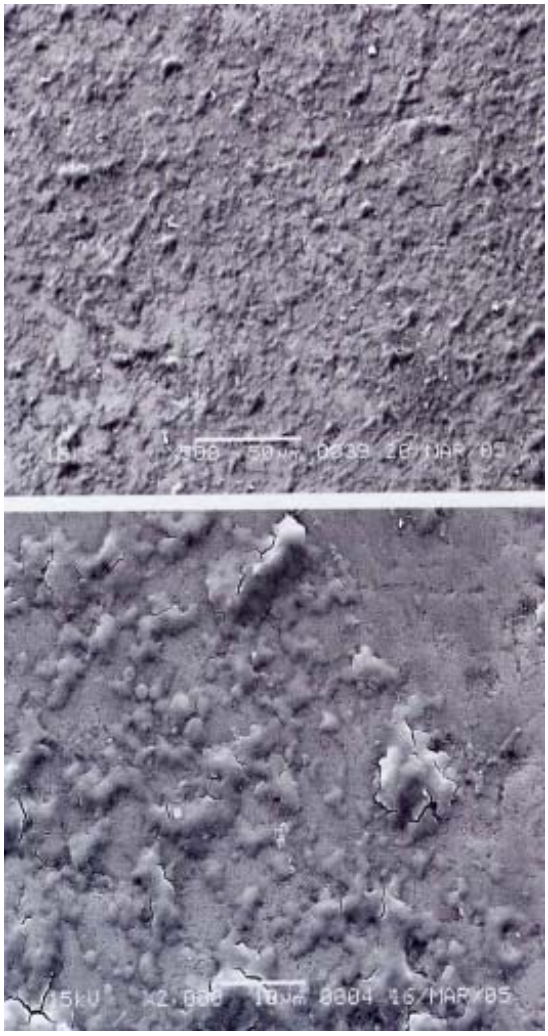

Fig. 5. SEM of enamel specimens treated with Bleach 10 (home bleaching, 10% carbamide peroxide). A precipitate was noted on the surface giving it a frosted appearance

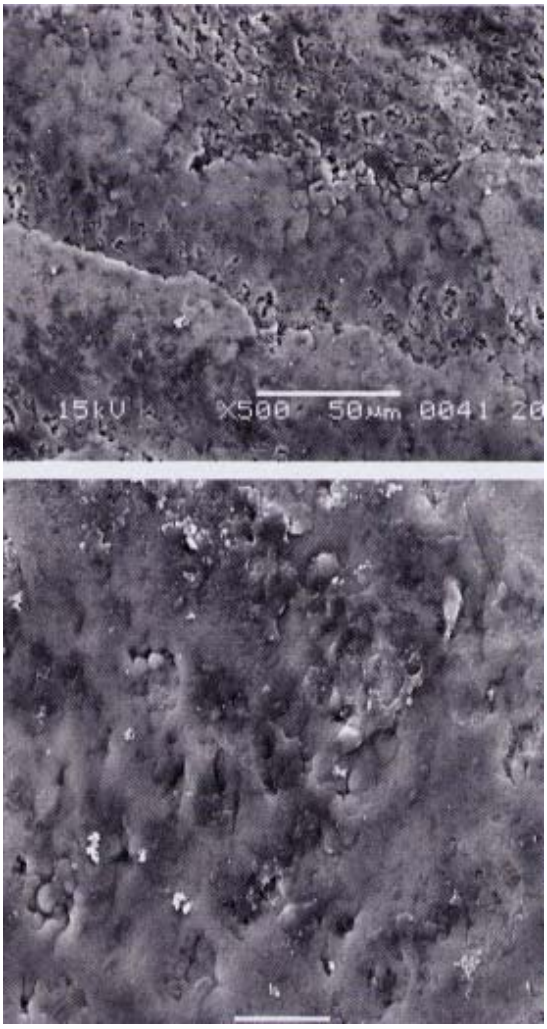

Fig. 6. SEM of enamel specimens treated with Natural White (OTC home bleaching). Irregular pattern of enamel erosion was evident with some precipitate on the surface.

also noticed in other studies.[15,16] These morphologic changes seemed to be as a result of partial removal of superficial layer of enamel, which is related to removal of organic precipitates, organic matrix of enamel and surface minerals.[13] Loss of minerals after treatment with different concentrations of carbamide peroxide such as 10% and 16% was also the finding of other studies.[17,18] Flaitz et al.[4] showed that different concentrations of carbamide peroxide can remove mineral structures from enamel, causing morphological alterations with different forms and intensity and can reach to the subsurface. In another study, Cimilli et al.[19] verified that different bleaching agents have been known to lower the Ca and P level in human enamel. Nevertheless, the morphological alterations in surfaces treated with the 10% carbamide peroxide (Bleach 10) and the 16% carbamide peroxide (Nite White) bleaching gels in

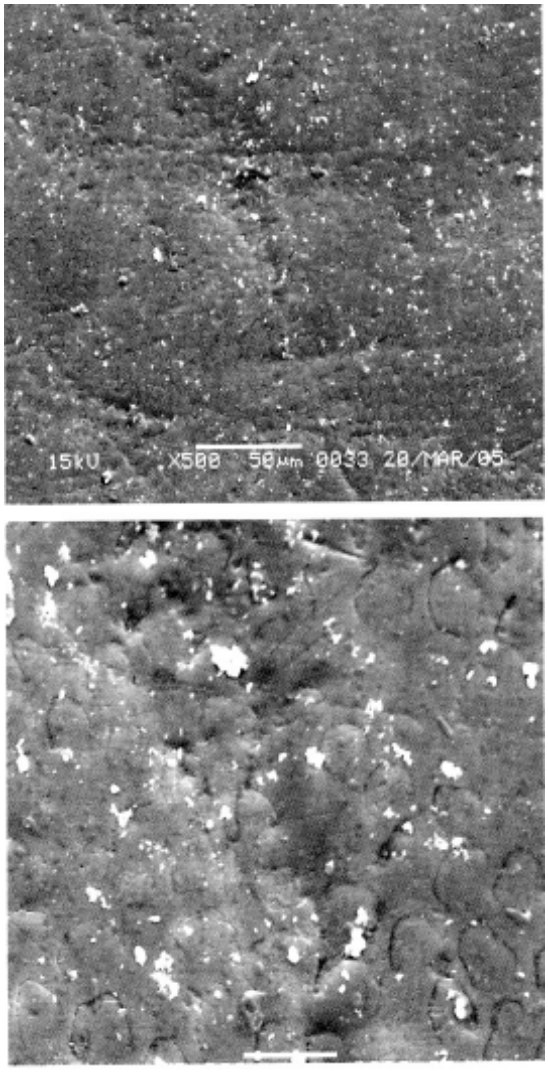

Fig. 7. SEM of enamel specimens treated with Rapid White Brush on (OTC home bleaching). Enamel surface showed shallow depressions with some residual debris

this study were different. The presence of precipitates that give frosted appearance to enamel surfaces treated with Bleach 10 probably due to the remineralization potential of the artificial saliva. Cyclic demineralization-remineralization phases associated with alternate exposure to the bleaching gels and artificial saliva, which contains calcium and phosphorus, was observed.[20] Bleach 10 also, contains fluoride, which will form CaF_2 like material. This material may be deposited on the surface of enamel sealing the surface.[21] The shiny white areas noticed on surfaces treated with Nite White were observed in another study[15] where they described these areas as "edge effect" a contrast factor for the SEM, which is generated from protrusions and circumferences of objects on specimen surface, causing them to appear brighter than do even surfaces.

Although Natural White bleaching gel contains hydrogen peroxide, (concentration is not indicated by the manufacturer), surface erosion and increase in surface pores was less evident in the SEM than the enamel surfaces treated with the 10% and 16% carbamide peroxide. This can be attributed to two factors. First, the time of exposure of enamel surfaces to Natural White gel was only 15 minutes daily, however, enamel surfaces were treated with 10% carbamide peroxide and the 16% carbamide peroxide for 4 hours daily as recommended by the manufactures. Second, the oral rinse that was recommended by the manufacture to be used after each exposure to Natural White gel contains sodium bicarbonate. This oral rinse in addition to the artificial saliva used in this study could protect the enamel surfaces treated with this type of gel.[20]

Rapid White and Rapid White Brush On bleaching gels are non peroxide agents. However, SEM showed changes in surface topography of enamel surfaces treated with these systems. The SEM of enamel surfaces treated with Rapid White bleaching gel showed more pores than the other two OTC products. This could be due to the presence of citric acid among the other components in Rapid White gel. Citric acid is known to demonstrate an erosive potential and softening effect on dental hard tissues.[22] Nevertheless, the round globules observed inside the pits in the SEM in this study are

possibly related to the remineralization potential of the artificial saliva. It might be speculated that these particles could block diffusion paths in enamel after bleaching, reversing the tooth hypersensitivity that sometimes occurs during the vital bleaching process.[23] The minor alterations that were observed in the SEM on enamel surfaces treated with Rapid White Brush On bleaching system may be related to other components in the gel. Glycerin, which is one component in Rapid White Brush On bleaching gel, could act as a demineralizing agent or as impermeable barrier, inhibiting the penetration of artificial saliva through the enamel surfaces.[24] The debris that was noticed on enamel surfaces might represent minerals, mobilized from prism peripheries deposited on the surfaces.

The SEM of the enamel surfaces treated with different bleaching products in this study showed morphological alterations of varying intensities. Nevertheless, the buffering capacity of saliva, the remineralization potential of saliva, oral hygiene, and the use of topical fluoride might overcome the detrimental effect of the bleaching products.[25,26] However, when teeth are to be whitened, it would be prudent to use a product and technique that are as efficacious as possible but which cause minimal side effect. Minor alterations of the enamel may permit future penetration of bacteria, debris or staining substances (coffee and tea), affecting the success of bleaching.[10] This emphasizes that at-home bleaching agents require professional supervision to ensure correct selection of the bleaching agent, proper application, recommended amount of gel/paste, length of treatment and steps to prevent adverse reaction.

CONCLUSIONS

1. The SEM of all surfaces treated with the different bleaching products, used in this study, showed surface alterations in enamel topography with varying intensities.
2. Hydrogen peroxide (35%) caused the most alteration in enamel morphology in this study.
3. The presence of fluoride in the bleaching product together with the remineralization potential of saliva overcome the demineralization caused by the bleaching product, as seen with enamel surfaces treated with Bleach 10.
4. Although the changes caused by the OTC bleaching products used in this study on enamel surfaces were less evident than the other professional products, it is recommended that all bleaching products used under professional supervision.

REFERENCES

1. Kugel G, Ferreira S. The art and science of tooth whitening. J Mass Dent Soc 2005; 53:34-37.
2. Perdigao J, Baratieri LN, Arcari GM. Contemporary trends and techniques in tooth whitening: A review. Pract Proceed Aesthet Dent 2004;16:185-192.
3. Haywood VB. Current concepts: Bleaching of vital teeth. Quintessence Int 1997;28:424-425.
4. Flaitz CM, Hicks MJ. Effects of carbamide peroxide whitening agents on enamel surfaces and caries-like lesion formation: An SEM and polarized light microscopy *in vitro* study. ASDC J Dent Child 1996;63:249-256.
5. Haywood VB. Nightguard vital bleaching current information and research. Esthet Dent Update 1990;1:20-25.
6. Dahl JE, Pallesen U. Tooth bleaching-a critical review of the biological aspects. Crit Rev Oral Biol Med 2003;14:292-304.
7. Chng HK. Update on materials used in intracoronal bleaching. Ann R Australas Coll Dent Surg 2002;16:147-150.
8. Viscio D, Gaffar A, Fakhry-Smith S, Xu T. Present and future technologies of tooth whitening. Compend Contin Educ Dent Suppl 2000;28: S36-43.

9. Oltu U, Gurgan S. Effects of three concentrations of carbamide peroxide on the structure of enamel. J Oral Rehab 2000;27:332-340.
10. Pinto CF, de Oliveira R, Cavalli V, Giannini M. Peroxide bleaching agent effects on enamel surface microhardness, roughness and morphology. Pesqui Odontol Bras 2004;18:306-311.
11. White DJ, Kozak KM, Zoladz JR, Duschner HJ, Gotz H. Effects of Crest Whitestrips bleaching on surface morphology and fracture susceptibility of teeth in vitro. J Clin Dent 2003;14:82-87.
12. LiY. Peroxide-containing tooth whiteners: An update on safety. Compend Contin Educ Dent Suppl 2000;28: S4-9.
13. Lopes GC, Bonissoni L, Baratieri LN, Vieira LC, Monteiro S Jr. Effect of bleaching agents on the hardness and morphology of enamel. J Esthet Restor Dent 2002;14:24-30.
14. Attin T, Muller T, Patyk A, Lennon AM. Influence of different bleaching systems on fracture toughness and hardness of enamel. Oper Dent 2004;29:188-195.
15. Spalding M, Taveira LD, Assis GF. Scanning electron microscopy of dental enamel surface exposed to 35% hydrogen peroxide: Alone, with saliva, and with 10% carbamide peroxide. J Esthet Resto Dent 2003;15:154-165.
16. Cavalli V, Arrais CA, Giannini M, Ambrosano GM. High-concentrated carbamide peroxide bleaching agents effects on enamel surface. J Oral Rehabil 2004;31:155-159.
17. Basting RT, Rodigues AL, Serra MC. The effect of seven-carbamide peroxide bleaching agents on enamel microhardness over time. J Am Dent Assoc 2003;134:1335-1342.
18. Potochik I, Kosec L, Gaspersic D. Effect of 10% carbamide peroxide bleaching gel on enamel microhardness, microstructure, and mineral content. J Endod 2000;26:203-206.
19. Cimilli H, Pameijer CH. Effect of carbamide peroxide bleaching agents on the physical properties and chemical composition of enamel. Am J Dent 2001;14:63-66.
20. De Freitas PM, Turssi CP, Hara AT, Serra MC. Monitoring of demineralized dentin microhardness throughout and after bleaching. Am J Dent 2004;17:342-346.
21. Pfarrer AM, White DJ, Featherstone JD. Anticaries profile qualification of an improved whitening dentifrice. J Clin Dent 2001;12:30-33.
22. Hughes JA, West NX, Addy M. The protective effect of fluoride treatments against enamel erosion *in vitro.* J Oral Rehabil 2004;31:357-363.
23. Nash RW. Tooth whitening and sensitivity reduction. Dent Today 2005;24:100-101.
24. Basting RT, Rodrigues AL Jr, Serra MC. The effect of 10% carbamide peroxide, carbopol and/or glycerin on enamel and dentin microhardness. Oper Dent 2005; 30:608-616.
25. Lewinstein I, Fuhrer N, Churaru N, Cardash H. Effect of different peroxide bleaching regimens and subsequent fluoridation on the hardness of human enamel and dentin. J Prosthet Dent 2004;92:337-342.
26. Pretty IA, Edgar WM, Higham SM. A study to assess the efficacy of a new detergent free, whitening dentifrice in vivo using QLF planimetric analysis. Br Dent J 2004;197:561-566.