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COLOR CHANGE AND SURFACE ROUGHNESS OF ENAMEL: PEROXIDE FREE VERSUS PEROXIDE CONTAINING WHITENING AGENTS

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ABSTRACT

Objective: to evaluate the effect of peroxide free versus peroxide containing whitening agents on color change and surface roughness of enamel.

Methods: A total of 30 bovine incisors were used for the current study. Teeth roots were sectioned and crowns were mounted in self-cured acrylic resin blocks. The teeth were randomly divided into three groups (n= 10) according to the whitening agent used: Group I: Control group (No treatment), Group II: Peroxide free whitening agent (BlanX White Shock toothpaste) and Group III: Peroxide containing whitening agent (White smile bleaching agent). The specimens were stained using black tea solution. BlanX toothpaste was used twice daily for 8 days while white smile bleaching material was applied for 3 sessions, 20 min each. Color change was assessed using VITA Easyshade spectrophotometer and surface roughness (Ra) was measured using a white light interferometer. Data were tabulated and statistically analyzed.

Results: Color change results revealed that both whitening agents were able to restore color comparable to the control group with no significant difference between them. Regarding surface roughness, no significant difference was reported between BlanX toothpaste and the control group which showed low surface roughness while white smile bleaching agent recorded the highest surface roughness value.

Conclusion: BlanX toothpaste was able to improve tooth color without altering enamel surface roughness. Although, white smile bleaching agent was effective in restoring tooth color, it negatively affects surface roughness.

KEY WORDS: Color change, Surface roughness, Peroxide free whitening agents, Peroxide containing whitening agents.

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INTRODUCTION

Today, aesthetics become an important issue for dental patients. Patients demands in recent years have been increased toward obtaining perfect white smile[1]. Teeth discoloration occur due to either intrinsic or extrinsic factors. The origin of extrinsic stains is mainly from smoking, poor oral hygiene or chromophore-containing foods as coffee and tea[2]. Organic and inorganic chromophores are adsorbed onto the tooth surface directly especially in presence of rough surfaces [3]. Therefore, whitening of teeth has become necessary procedure to improve their color [4].

Teeth bleaching is considered one of the most common minimally invasive esthetic treatments for discolored natural teeth [5]. Whitening of tooth color depends on multiple factors including type of stain, bleaching agent, and treatment protocol [6]. Different techniques of teeth bleaching were reported in literature as in-office bleaching, at-home bleaching, and over-the-counter bleaching agents [7]. In general, in-office and at-home bleaching techniques are based on different concentrations of hydrogen peroxide and carbamide peroxide respectively. Carbamide peroxide decomposes into hydrogen peroxide and urea [8]. The action of hydrogen peroxide is based on the release of reactive oxygen particles that diffuse through the enamel surface and act on dentin by breaking down high-molecular carbon rings of the chromophore molecules into smaller ones. These smaller molecules diffuse to the tooth tissues providing the desired color change [9].

Many patients prefer to use the whitening toothpastes as they have low-cost and are easily obtained from pharmacies, supermarkets, and online shopping [10]. Whitening dentifrices represent more than 50% of the over-the-counter products with a great variety of components [11]. The action of whitening toothpastes depends on the presence of either abrasive components such as hydrated silica, calcium carbonate, sodium bicarbonate, dicalcium phosphate dihydrate, calcium pyrophosphate, alumina, and perlite, or bleaching compounds as hydrogen peroxide, sodium citrate, sodium percarbonate, calcium and magnesium peroxide, and phosphate salt [4, 12]. Other whitening dentifrices contain whitening agents that adsorb pigments and stains as activated charcoal [13] or modify the color perception such as blue covarine [14].

Nowadays, the evolution of new whitening formulations with alternative ingredients and additives supposed to have minimal effect on tooth surface properties [15]. BlanX white shock toothpaste is a new formula of peroxide-free non-abrasive toothpaste which is based on Actilux technology. This technology is based on activation of Actilux micro-crystals to whitens the teeth using light. It is activated either by a special LED light accelerator which is supplied with the toothpaste or natural sun light. The manufacturer postulates that BlanX toothpaste can restore natural white smile as the more you smile, the whiter teeth you can get.

Surface roughness is an important indication that shows the undesired effect of whitening agents [16]. Although bleaching agents and whitening toothpastes positively affect tooth color, they could negatively affect surface roughness of enamel [17]. Previous studies [16, 18, 19] reported the deleterious effect of whitening toothpastes on mineral content of hard tooth tissues where they resulted in increased enamel surface roughness. Therefore, this study was conducted to evaluate the effect of peroxide free versus peroxide containing whitening agents on color change and surface roughness of enamel.

MATERIALS AND METHODS

Specimens' Preparation and Grouping

Thirty intact bovine incisors were used in the present study. The teeth were washed under running water, scaled from adhering soft tissue, plaque, and then stored at 4ºC in distilled water for not more than one month. Teeth roots were cut 2 mm below the cemento-enamel-junction. The coronal portions were mounted in self-cured acrylic resin blocks using metal molds (2 cm x 3 cm) with the labial surface facing upward. Enamel was wet ground using 80 grit sandpaper discs to achieve flat enamel surfaces. Enamel surfaces were abraded with 400 and 600 grit sandpaper discs, and polished with rubber cups and paste to achieve smooth surfaces. After polishing, the specimens were cleaned in an ultrasonic cleaning device (Wisd, WUC-D06H, DAIHAN Scientific Co,Ltd, Korea) with deionized water for 15 min to remove any debris.

The specimens were randomly divided into three groups (n= 10) according to the tested whitening agents (table 1) as follows: Group I: Control group (no treatment), Group II: Peroxide free whitening agent (BlanX White Shock toothpaste) and Group III: Peroxide containing whitening agent (White smile bleaching agent).

Staining of the Specimens

The specimens were stained using black tea solution for 5 days (Yellow Label, Lipton black tea, London, United Kingdom). The solution was prepared by immersing two tea bags (2 x 2.0g) into 200 mL of boiling water for 5 min then filtered with a piece of gauze. The tea solution was changed every 24 h. The five days immersion represents one year of drinking supposed that one dose 200 ml of tea consumption lasts for 5 min, given that four doses are consumed daily by regular tea drinkers [20].

Whitening Procedures

Regarding BlanX group, the specimens were brushed twice daily (morning and evening) for 2 min for a total of 8 days using electric toothbrush (Oral-B Vitality Plus, cross action electronic toothbrush powered by Braun, Germany). BlanX toothpaste was supplied with a special LED accelerator. According to the manufacturer instructions, BlanX LED accelerator was screwed onto the toothpaste tube instead of the screwing cap to apply LED light on the toothpaste (Fig. 1) while it is being placed onto the toothbrush immediately to activate the Actilux microcrystals to achieve the desired whitening effect. For group III, white smile bleaching agent was applied in a uniform thickness, left for 20 min and then rinsed using copious amount of water. This procedure was repeated for three sessions according to the manufacturer's instructions.

TABLE (1) Materials used in the current study

Material (Description)	Composition	Lot No. and Manufacturer
BlanX White Shock Toothpaste with special LED accelerator light (Actilux-activated peroxide-free, non-abrasive whitening toothpaste)	Aqua, sorbitol, hydrated silica, glycerin, silica, sodium lauryl sulfate, cellulose gum, aroma, hydroxyapatite*, Actilux microcrystals, isopropyl alcohol, phenoxyethanol, sodium monofluorophosphate, sodium benzoate, benzyl alcohol, CI 77891, CI 42090, PVM/MA copolymer, cetraria islandica extract, sodium	14093 Coswell, Italian Innovators, Italy www.Coswell.biz
White Smile (Bleaching agent)	40% hydrogen peroxide	21006 Power whitening YF, GmbH, Germany. www.whitesmile.de

Fig. (1) BlanX White Shock toothpaste supplied with a LED light accelerator

After whitening procedures, the specimens were washed with distilled water then stored in artificial saliva after brushing which was changed every 24 h. Artificial saliva was prepared according to *Vieira-Junior et al 2016* [21] as follows: 1.5 mM Ca, 0.9 mM P, 150 mM KCL, 0.05 lg F/mL, and 0.1 M Tris buffer, set to a pH of 7.0.

Color Assessment

Color of the specimens was assessed before any treatment (baseline) according to CIE (Lab) color system (Commission Internationale de L'Eclairage) by using a VITA Easyshade spectrophotometer (Advance 4.01, VITA Zahnfabric, Bad Sackingen, Germany) against a white background. According to this system, the three different color parameters L*, a* and b* were calculated as follow: L* value denotes darkness–brightness (range from 0 to 100); a* value represents the green–red component (ranging from–80 green to +80 red) and b* represents the blue–yellow component (values ranging from –80 blue to +80 yellow). Color of the middle portion of each specimen was recorded [22]. The color changes were further assessed after staining and after the whitening procedures and color change (ΔE) was then calculated according to the following formula:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$ [13,22].

Surface Roughness Assessment

Surface roughness was measured using a white light interferometer. This was carried out using ZYGO Maxim-GP 200 profilometer, which is a general purpose surface optical profiler that measures the microstructure and topography of surfaces in three dimensions. Computerized phase stepping interferometry (PSI) upgraded with scanning white light interferometry (SWLI) and advanced surface texture software was used which analyzes areas as well as profiles and step height. A white light from a halogen lamp incident on an interference filter with Full Width at Half Maximum (FWHM) ≈3 -15 nm was used depending on the measuring technique. Three readings were recorded for each specimen and an average value was calculated to represent the surface roughness for each specimen in µm.

Statistical Analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Color change data showed non-normal (non-parametric) distribution while surface roughness data showed normal (parametric) distribution. Data were presented as mean, standard deviation (SD), median and range values. For non-parametric data; Mann-Whitney U test was used to compare between the two whitening agents. For parametric data; one-way ANOVA test was used to compare between the three groups. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test revealed significance. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

Color Change Results

Results of color change revealed that both whitening agents were able to restore color comparable to the control group with no significant difference between them. Results of ΔE showed no significant difference between the two whitening agents after staining with a *P*-value = 0.602. Also, no significant difference was recorded between both whitening agents after whitening compared to after staining (*P*-value = 0.251) and after whitening compared to base line (*P*-value = 0.346).

Regarding ΔL, no statistically significant difference was found between the two whitening agents after staining (*P*-value = 0.917), after whitening compared to after staining (*P*-value = 0.917) as well as after whitening compared to base line (*P*-value = 0.530).

Results of Δa and Δb reported no significant differences between both whitening agents after staining (*P*-value = 0.209) and (*P*-value = 0.602) respectively. Also, no significant difference was recorded after whitening compared to after staining with *P*-value = 0.602 for Δa and *P*-value = 0.465 for Δb as well as after whitening compared to base line with *P*-value = 0.465 and *P*-value = 0.754 for Δa and Δb respectively.

TABLE (2) Descriptive statistics and results of Mann-Whitney U test for comparison between the color parameters of the two whitening agents

Color parameters	Time	BlanX		White Smile		*P*-value	Effect size *(d)*
		Mean (SD)	Median (Range)	Mean (SD)	Median (Range)		
ΔE	Base line - Staining	13.42 (3.37)	11.61 (10.84-18.93)	13.52 (2.25)	13.82 (10.95-16.53)	0.602	0.335
	Staining – Whitening	19.14 (3.43)	17.19 (16.51-24.57)	21.31 (2.82)	21.2 (17.95-24.39)	0.251	0.78
	Base line - Whitening	8.12 (3.05)	7.73 (5.15-13.11)	10.01 (3.62)	10.53 (6.56-15.53)	0.346	0.623
ΔL	Base line - Staining	-9.59 (2.25)	-9.48 (-12.42- -6.21)	-9.58 (3.04)	-9.64 (-13.34- -4.94)	0.917	0.066
	Staining - Whitening	15.2 (3.94)	16.43 (9.17-19.32)	15.82 (1.42)	15.29 (14.13-17.41)	0.917	0.066
	Base line - Whitening	5.62 (2.61)	5.01 (2.96-9.84)	6.24 (2.4)	5.99 (4.07-10.13)	0.530	0.404
Δa	Base line - Staining	1.59 (0.62)	1.66 (0.57-2.14)	2.04 (0.37)	2.05 (1.66-2.63)	0.209	0.863
	Staining - Whitening	-3.36 (0.65)	-3.34 (-3.97- -2.38)	-3.19 (0.54)	-3.47 (-3.59- -2.36)	0.602	0.335
	Base line - Whitening	-1.76 (1.09)	-1.34 (-3.36- -0.72)	-1.15 (0.33)	-1.15 (-1.51- -0.7)	0.465	0.475
Δb	Base line - Staining	7.38 (6.69)	7 (-2.38-16.3)	6.72 (6.93)	4.77 (-2.47-15.64)	0.602	0.335
	Staining - Whitening	-10.25 (4.4)	-10.04 (-14.67- -3.29)	-12.79 (6.61)	-14.39 (-19.56- -4.65)	0.465	0.475
	Base line - Whitening	-2.87 (5.49)	-4 (-7.99-6.36)	-6.07 (6.02)	-3.27 (-14.79- -0.12)	0.754	0.199

: Significant at P ≤ 0.05

Surface Roughness (Ra) Results

Results recorded a statistically significant difference between Ra of the three tested groups (*P*-value <0.001). Pair-wise comparison between groups revealed that there was no statistically significant difference between control group and BlanX group. Both groups showed statistically significant lower mean Ra value than White Smile which showed the highest mean Ra value of all experimental groups.

TABLE (3) Descriptive statistics and results of one-way ANOVA test for comparison of Ra values (μm) for all experimental groups

Group	Mean	SD	*P*-value	Effect size *(Eta squared)*
Control	0.291 ^{B}	0.037		
BlanX	0.285 ^{B}	0.018	<0.001*	0.954
White Smile	0.883 ^{A}	0.105		

: Significant at $P \leq 0.05$, Different superscripts indicate statistically significant difference

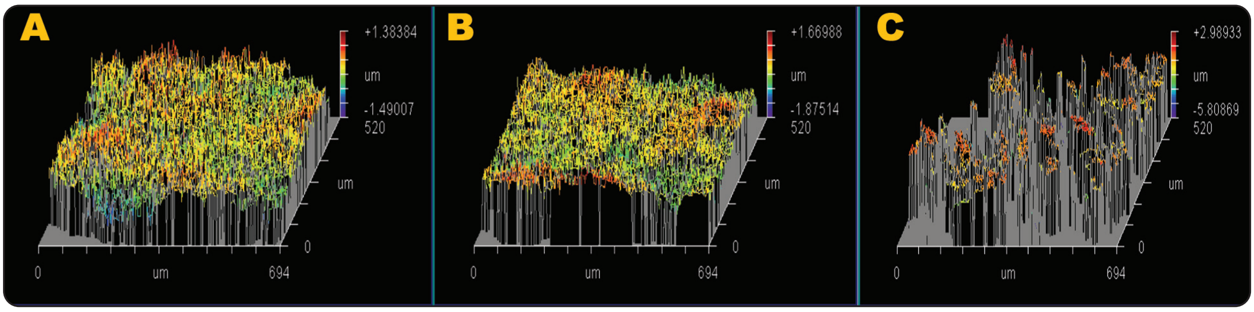

Fig. (2) Surface roughness of the three experimental groups; A: Control group, B: BlanX toothpaste and C: White Smile bleaching agent

DISCUSSION

The current study was carried out to evaluate the effect of peroxide free (BlanX White Shock toothpaste) versus peroxide containing (White Smile bleaching agent) whitening agents on color change and surface roughness of enamel. The bovine teeth were used in this study as their physical and chemical properties are very similar to those of human teeth [(21)].

White teeth have always been considered essential demand for an esthetic smile. Teeth whitening are available in different activation modes, application methods, concentrations, and bleaching agents which are applied either manually or professionally [(23)]. Although all techniques are shown to be effective for achieving satisfactory whitening outcomes, the higher hydrogen peroxide concentration produces faster results with reduced application time [(24)].

Results of color change revealed that ΔE showed no significant difference between BlanX toothpaste and White Smile bleaching agent after whitening compared to after staining and after whitening compared to base line. Both whitening agents have shown an increase in L* values and decrease in a* and b*. Whereas, a positive L* value after whitening means that the teeth become whiter, while the negative values of a* and b* indicate that the teeth tend to be less yellowish and less reddish respectively.

BlanX toothpaste does not contain peroxide ingredients so, its whitening effect is attributed to the presence of Actilux micro-crystals. These micro-crystals are patented combination of titanium dioxide and hydroxyapatite. Titanium dioxide is known as intense white pigment that has a high refractive index and is widely used in toothpaste formulations. It binds to enamel during regular teeth brushing, creating an invisible barrier which obstructs the causes of discoloration. Moreover, its special LED light accelerator activates the photocatalytic active ingredient of Actilux that destroy the stain molecules and lasts all day to naturally whiten the teeth as reported by the manufacturer. These results were in agreement with previous studies [25,26] which reported that BlanX toothpaste had a significant whitening effect on enamel.

On the other hand, the whitening effect of White Smile bleaching agent is attributed to the presence of 40 % hydrogen peroxide that is considered the main component commonly used in bleaching agents. The mechanism of action of hydrogen peroxide on tooth surface is based on the release of reactive oxygen molecules. These low molecular weight reactive oxygen molecules diffuse through the inter-prismatic spaces breaking long chain complex chromophore molecules into smaller ones, providing the desired color change [9, 27].

This finding agreed with other studies [24,28] which showed that the high concentrations of hydrogen peroxide bleaching agents produce more noticeable color change. However, previous researches [29, 30] demonstrated that low concentrations of peroxide are able to provide acceptable color change. This may be attributed to the difference in assessment method or percentage of hydrogen peroxide.

Although, teeth whitening is considered conservative non-destructive treatment for discolored teeth, previous studies [24, 31] have shown that whitening agents might have an adverse effect on surface morphology, chemical composition, and microhardness of the bleached enamel surface. The available tooth whitening products in the market are mostly dependent on the presence of either peroxide or abrasive components which may lead to an undesirable effect on teeth surfaces as increasing surface roughness and wear of enamel [18]. Therefore, an ideal whitening agent should improve color without affecting enamel surface [32].

Surface roughness (Ra) results revealed insignificant difference between the control group and BlanX toothpaste where both showed significantly lower mean Ra than white smile bleaching agent. This might be explained by the absence of abrasive component of the BlanX toothpaste. Another possible explanation might be attributed to the presence of hydroxyapatite micro-crystals in its composition which have similar structure to the main mineral component of teeth. Moreover, it provides a source of calcium and phosphate ions that enhance enamel remineralization [33]. Furthermore, BlanX toothpaste contain sodium monofluorophosphate that may accelerate the remineralization process through fluorapatite formation [34]. As there were no available studies in the literature about the effect of BlanX toothpaste on surface roughness of enamel, the result of this study cannot be directly compared.

However, White smile bleaching agent recorded the highest mean Ra value. The increase in enamel surface roughness may be attributed to its hydrogen peroxide content that causes dissolution of the inorganic components of the enamel through penetrating the intra / interprismatic areas results in rough enamel surface [35]. Furthermore, the micromorphological observation of peroxide containing bleaching agent on enamel reported exaggerated prism irregularities with subsequent increased enamel surface roughness [36]. In addition, hydrogen peroxide decomposes to release free radicals during the bleaching process which can increase the surface porosity, as free radicals react with the organic components of hard tooth tissues [37].

This finding was in accordance with recent studies[35, 38]. However, it disagreed with a previous study[28] that revealed no significant changes in enamel surface roughness before and after bleaching. This difference may be attributed to multiple factors including the assessment method, hydrogen peroxide percentage as well as the study design.

CONCLUSION

Within the limitations of the current study, it could be concluded that BlanX toothpaste was able to improve tooth color without altering enamel surface roughness. Although, white smile bleaching agent was effective in restoring tooth color, it negatively affects surface roughness.

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