Article published online: 2021-11-01

Original Article

Safety Comparison of Over the Counter Bleaching with Professionally Prescribed Home Bleaching Agent

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Abstract

Aims: This aimed to compare the colour changes, microhardness, and surface roughness of the human natural tooth after bleaching treatment with a professional home bleaching agent and over-the-counter (OTC) bleaching agent. **Settings and Design:** This was an *in vitro* study using extracted human teeth stained with human blood as specimens. **Materials and Methods:** Fifty-seven human natural teeth were embedded in acrylic of 2.5 mm thickness and 14 mm × 8 mm surface area. The samples were stained with human blood before they were divided into three groups (n = 19 per group) of control (C), Professional Bleaching Opalescence PF 15% (PB), and OTC Whitelight Tooth Whitening set (WL) before being treated with the respective bleaching agents for 10 days. Color changes were measured as colorimetric measurements (L*, a*, and b* values) were recorded during prestaining, poststaining, and postbleaching, while microhardness and surface roughness measurements were recorded for pre- and postbleaching. **Statistical Analysis:** Statistical analysis was done with SPSS (IBM Statistic, California, USA) version 22.0. Paired t-test and nonparametric analysis (Wilcoxon Signed-Rank Test) were used to analyze the data. P value was set as significant at $P < 0.05$. **Results:** The color changes in PB group was not significantly better compared with WL group (PB: 12.2 [4.07] and WL: 12.2 [4.32]). Whereas significant difference was noticed in microhardness after bleaching in PB group with a higher VHN number (500.4 [121.10]) compared with WL group (471.0 [114.47]) . The surface roughness (Ra) remain the same for all experimental groups. **Conclusions:** Both professional home bleaching agent and OTC bleaching agents showed similar efficacy, with no effect on surface roughness, and both caused an increase in microhardness.

Keywords: Home bleaching, over the counter bleaching, professionally prescribed home bleaching

Introduction

Tooth discolouration is a resultant of varied and complex causes that are either intrinsic or extrinsic in nature.[1] There is a wide range of cosmetic problems arising from tooth discolouration which has led to the public striving for a more esthetically pleasing and presentable appearance.[2] Tooth bleaching procedures have become increasingly popular worldwide[3] as it is an effective and noninvasive treatment if compared to other treatments such as veneer placement and full coverage indirect restorations.[4-6]

The three rudimentary approaches for bleaching vital teeth include in-office or power bleaching, at-home or dentist supervised nightguard bleaching, and bleaching with over-the-counter (OTC) products.[7] OTC bleaching method is gaining attention in the market lately because it can be used without the dentist's supervision. It is simpler, less expensive, less complicated, and requires less in-office time.[8] However, there are concerns over its safety and efficacy besides the potential abuse of the products by the public since it is easily available to them.[8] The people tend to overlook the importance of consulting professional advice on tooth bleaching. In fact, the efficacy of OTC bleaching agents remains a question as there is a lack of clinical trials that are able to provide substantial scientific background regarding these bleaching products.[9]

Access this article online

Quick Response Code:

Website: www.ejgd.org

DOI: 10.4103/ejgd.ejgd_27_18

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How to cite this article: Singh JK, Sengut M, Halim MS, Ab-Ghani Z, Rahman NA. Safety comparison of over the counter bleaching with professionally prescribed home bleaching agent. Eur J Gen Dent 2018;7:35-40.

The efficacy of bleaching agent can be determined clinically by measuring the color change of the tooth after the bleaching regimen.[10] A change in tooth color after completing the bleaching regimen was reported with all methods of tooth bleaching.[11] Pinto *et al*. reported that, after completing the bleaching regimen, all bleaching agents promoted a reduction in enamel microhardness and an increase in surface roughness.[12] Although tooth bleaching does not create macroscopically visible defects, microscopic alterations could eventually cause undesirable effects.[13] Rough surfaces manifested from tooth bleaching may predispose that area to extrinsic staining, bacteria adhesion, plaque maturation, and periodontal disease which may lead to even serious problem as a consequence.[14]

As a comparison to both methods of tooth bleaching, professional-prescribed home bleaching method has been found to be more superior in terms of color changes with OTC bleaching method.[15] Another report found that professional-prescribed home bleaching method was the most effective method of tooth bleaching.[11]

Due to a limited study done on the comparison between color changes, enamel microhardness, and surface roughness, therefore, this study would like to compare the efficacy of professional home bleaching agent and OTC bleaching agent in bleaching tooth stained with human blood. The findings of this study would help to increase the community's awareness with regard to the different tooth bleaching techniques available in dentistry and help them to choose the bleaching agent which is effective and caused only minimal harm to their dentition.

Materials and Methods

Fifty-seven sound human permanent maxillary central and lateral incisors were collected from Outpatient Dental Clinic Hospital Universiti Sains Malaysia (HUSM). The teeth were extracted from patients with periodontal problem. The patients were given explanation on the research procedure, and their teeth will be discarded after the research. After the extraction, the tooth specimens were kept in thymol solution until sample preparation stage.

The tooth specimens were cleaned from debris with prophylaxis cup and pumice mounted on slow speed handpieces. Then, each tooth was embedded in self-curing clear acrylic resin (Vertex, The Netherlands) with labial surface of the tooth facing the mold base.[16] Roots of the embedded teeth were cut and removed. The labial surface of the tooth was exposed by trimming off the excess acrylic using acrylic bur. The acrylic was flattened using the model trimmer to obtain even surface, and the size of specimen was standardized to 14 mm × 8 mm (±1 mm).[16] Then, samples were trimmed again to 2.6 mm thickness and were polished using sandpaper of decreasing grits of 500, 2500, and 5000 μm (WS-FLEX 18, HERMES) providing finished section of 2.5 mm thickness and 14 mm × 8 mm area.

Tooth specimens (2.5 mm thickness and 14 mm × 8 mm area) were labeled then were divided randomly into three groups of 19. Baseline measurement for color, surface microhardness, and surface roughness were taken before staining procedure was done.

The samples were stained with human blood using slight modification from that of the technique introduced by Freccia and Peters.[17] Enamel of the tooth was first etched to remove smear layer using 37% phosphoric acid (SL Etchant Gel, SwissTEC) for 15 s and was rinsed using copious water.[16] Thirty milliliters of human blood obtained from HUSM blood bank was filled into each centrifuging tube and was centrifuged at 5000 rpm for 10 min. Then, the blood plasma was removed from centrifuging tubes and distilled water was added until total volume reaches 35 ml. Blood was centrifuged again at 5000 rpm for 10 min resulting in rich-hemoglobin hemolysate blood solution. Samples were left in the centrifuging tube for 24 h. All the tubes were then centrifuged at 5000 rpm for 20 min, once a day, for 4 consecutive days with 24 h interval. After completing the cycles, samples were rinsed using distilled water. All samples were kept in 100% relative humidity at 37°C for 7 days before color measurement procedure.[16]

Table 1 shows the bleaching agent's manufacturer, composition, bleaching regimens used, and pattern number. The control group was kept in 100% relative humidity at 37°C for 10 days. For PB group, Opalescence PF 15% Mint was applied about 1 mm thickness on the labial surface of the tooth samples using microbrush. Then, samples will be kept in 100% relative humidity at 37°C before rinsing it thoroughly with distilled water 4–6 h later. For WL group, the tooth whitening gels were applied about 1 mm thickness on the labial surface of the tooth sample. After that, the tooth will be exposed to light transmitter (simple light-emitting diode light provided by the manufacturer) for 10 min each. There is no manufacturer instruction on how many days this product

Table 1: Bleaching Product Investigated

Group	Bleaching agent	Active ingredient	Other ingredients	Regimens	Patent number
1	Opalescence PF 15% Mint (Ultradent Products Inc., South Jordan, USA) (PB)	15% carbamide peroxide	Glycerin, Water, Xylitol, Carbomer, PEG-300, Sodium Hydroxide, EDTA, Potassium Nitrate, Sodium Fluoride	1 daily application (4-6 h) for 10 days	89494.5
2	The WhiteLight™ System (USA) (WL)	Carbamide peroxide	Glycerin, Water, Povidone, Silica, Sodium Hydroxide, Sodium Saccharin, K12.Sorbitol.EDTA	1 daily application (10 min with light transmitter)	03364755.0

must be used. However, cycle was repeated daily for 10 days for standardization purpose. After completing every cycle of bleaching, tooth samples were kept again in 100% relative humidity at 37°C.

Shade of the tooth samples was measured using a digital spectrophotometer VITA Easyshade Advance 4.0 (VITA Zahnfabrik H. Rauter GmbH and Co. KG, Germany) before staining, after staining, and after bleaching procedure. Before color measurement, the samples were rinsed with distilled water and were dried using absorbent tissue. Samples were placed on a white paper during measurement to avoid disturbance in spectrophotometer reading from surrounding. The instrument was used to measure only at the central area of the tooth sample for basic shade measurement. The probe tip was placed perpendicular and in contact with the tooth surface. While holding the probe tip steadily against the enamel tooth surface, measurement button and the probe tip were held against the tooth until two rapid "beeps" heard that indicate the completion of the measurement. Then, the results displayed were recorded. The measurement will record L*, a*, b*, where L* stands for luminosity dimensions or whiteness, ranging from 0 (pure black) to 100 (reference white), a * for green-red contrast (−a* = green and + a* = red), and b* for blue-yellow contrast (−b* = blue and + b* = yellow). Color change (ΔE) was calculated using formula: $\Delta E = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{½}$. Positive ΔL* means the samples became whiter, whereas negative ΔL* means samples became darker.[18]

Microhardness testing of the enamel was done before and after bleaching using Vickers hardness tester (VM 50; Fuel Instruments and Engineers Pvt. Ltd., Maharashtra, India). Each sample was observed through fitted microscope (×10) for selecting the indentation area by placing it on the test base. The Vickers hardness indenter was set with 10 kg load for 20 s. Three indentations were made for each sample before and after application of bleaching agent, and the readings were recorded. Average value of the samples microhardness was calculated.

Surface roughness measurement was done using a profilometer (Surfcom Flex-50A, Tokyo Seimitsu Co., Ltd., Japan) as baseline measurement and after bleaching application. This profilometer has measuring a range of ±400 μm for Z-axis direction, 50 mm for X-axis direction, with measuring resolution of 0.00016 μm/±4 μm and 0.016 μm/±400 μm. The measuring speed available in four different speeds that is 0.15, 0.3, 0.6, and 1.5 mm/s. In this study, we used speed of 0.15 mm/s and evaluation length of 2 mm. Three different readings were taken for each specimen. Average measurement readings were then calculated.[12]

Results

Three groups of samples completed the study, namely, control (C), sample bleached with Opalescence PF 15% (PB),

Table 2: Colorimetric assessment after staining (L*, a*, b* values)

Group	Variables	Pre-staining mean (SD)	Post-staining mean (SD)	Mean difference (95% CI)	*t*-statistics (df)[a]	*P*
Control	L value	89.9 (5.28)	63.6 (7.13)	26.4 (22.73, 29.99)	15.25 (18)	<0.001
	a value	-0.1 (3.00)[b]	0.7 (4.77)[b]	-	-	0.763[c]
	b value	31.5 (6.13)	21.0 (4.50)	10.5 (8.12, 12.80)	9.36 (18)	<0.001
Opalescence PF 15% (PB)	L value	87.8 (4.92)	64.4 (4.71)	23.4 (19.98, 26.73)	14.55 (18)	<0.001
	a value	0.5 (2.50)[b]	-0.4 (2.37)[b]	-	-	0.198[c]
	b value	30.4 (6.43)	21.7 (4.06)	8.8 (6.49, 11.05)	8.07 (18)	<0.001
White light Tooth Whitening (WL)	L value	89.7 (4.27)	66.5 (2.80)	23.2 (20.77, 25.59)	20.23 (18)	<0.001
	a value	0.3 (1.80)[b]	-0.8 (2.37)[b]	-	-	0.091[c]
	b value	32.2 (6.06)	20.9 (4.45)	11.3 (9.30, 13.30)	11.89 (18)	<0.001

[a]Paired *t*-test, [b]Median (IQR), [c]Wilcoxon Signed Rank Test (*Z*-statistics)

Table 3: Colorimetric assessment after bleaching (L*, a*, b* values)

Group	Variables	Post-staining Mean (SD)	Post-bleaching Mean (SD)	Mean difference (95% CI)	*t*-statistics (df)[a]	*P*
Control	L value	63.6 (7.13)	63.6 (7.13)	-	-	-
	a value	0.7 (4.77)[b]	0.7 (4.77)[b]	-	-	-
	b value	21.0 (4.50)	21.0 (4.50)	-	-	-
Opalescence PF 15% (PB)	L value	64.4 (4.71)	75.6 (4.98)	-11.1 (-13.28, -8.96)	-10.82 (18)	<0.001
	a value	-0.4 (2.37)[b]	-0.8 (1.37)[b]	-	-	0.025[c]
	b value	21.7 (4.06)	18.0 (4.68)	3.7 (2.43, 4.96)	6.14 (18)	<0.001
Whitelight Tooth Whitening (WL)	L value	66.5 (2.80)	77.7 (5.69)	-11.2 (-13.18, -9.18)	-11.75 (18)	<0.001
	a value	-0.8 (2.37)[b]	-0.6 (1.40)[b]	-	-	0.856[c]
	b value	20.9 (4.45)	24.7 (5.14)	-3.8 (-5.33, -2.19)	-5.05 (18)	<0.001

[a]Paired *t*-test, [b]Median (IQR), [c]Wilcoxon Signed Rank Test (*Z*-statistics)

and sample bleached with Whitelight Tooth Whitening set (WL).

Table 2 displays the mean (standard deviation [SD]) values or median (interquartile range) of L*, a*, and b* values obtained from the colorimetric measurement for all groups for pre- and poststaining with human blood. The L*, a*, and b* values did not show any significant difference between the groups, showing the samples were properly randomized. For all groups, there was a significant change in L* and b* values ($P < 0.001$) after staining the samples but not for the a* value.

Table 3 shows the mean (SD) values of L*, a*, and b* values obtained from the colorimetric measurement for all groups for prebleaching (poststaining) and postbleaching. PB group shows significant difference for L* value, b* value ($P < 0.001$), and a* value ($P = 0.025$). L* value for PB group increased by 11.1, while the b* value decreased by 3.7 after bleaching regimen. For the WL group, only L* and b* value showed a significant difference ($P < 0.001$), while changes for a* value were not significant. L* value for WL group increased by 11.2, while b* value increased by 3.8.

Table 4 shows the mean color changes (ΔE), the difference in microhardness, and the difference in surface roughness after completing the bleaching regimen. PB group and WL group both recorded a color change with a mean of 12.2 after bleaching, respectively. PB group showed a significant difference of microhardness after bleaching ($P < 0.001$) and an increment of the microhardness by 143.1. On the other hand, WL also showed a significant difference with an increment of 109.6 ($P = 0.001$). For surface roughness measurement, both PB group and WL group did not show any significant difference in surface roughness after bleaching ($P = 0.389$ and $P = 0.491$, respectively).

Table 5 summarizes the changes in test parameters for the two experimental groups. For color changes after bleaching, two pairs of group have significant difference after bleaching which is control-PB group and control-WL group ($P < 0.001$). However, there is no significant difference for the pair PB-WL. As for the difference in microhardness, two pairs of group have significant difference after bleaching which is control-PB group ($P < 0.001$) and control-WL group ($P = 0.001$). There is no significant difference for the pair PB-WL. There was no significant difference noticed between the groups for difference in surface roughness after bleaching ($P = 0.733$).

Discussion

This study was carried out to determine the efficacy and effect of professional home bleaching agent and OTC bleaching agent on human natural tooth by measuring color changes, difference in microhardness, and difference in surface roughness.

It is difficult to observe the color changes on samples in bleaching assessment without staining it. Thus, in this study, we used the staining technique from study conducted by Freccia and Peter in 1982.[17] According to this method, it is believed that the intrinsic tooth discoloration was due to the oxidation of hemoglobin inside dentinal tubules. After centrifuge, the blood was separated into two distinct phases: a continuous, liquid, yellowish phase called plasma, and a discontinuous, red, dense phase represented by the blood cells, thus containing

Table 4: Comparison of colour changes, microhardness and surface roughness in opalescence PF 15% and whitelight tooth whitening pre and post-bleaching

Group	Assessment Parameters	Pre-bleaching Mean (SD)	Post-bleaching Mean (SD)	Mean difference (95% CI)	*t*-statistics (d*f*)[a]	*P*
Opalescence PF 15% (PB)	Colour changes	25.6 (6.24)	12.2 (4.07)	13.40	9.267 (18)	0.000
	Microhardness	357.3 (57.04)	500.4 (121.10)	-143.1 (208.22, -78.10)	-4.63 (18)	<0.001
	Surface roughness	0.5 (0.14)	0.5 (0.11)	0.0 (-0.03, 0.07)	0.88 (18)	0.389
Whitelight tooth whitening (WL)	Colour changes	26.3 (4.28)	12.2 (4.32)	14.04	-4.182 (18)	0.000
	Microhardness	361.4 (41.75)	471.0 (114.47)	-109.6 (-164.68, -54.55)	-4.18 (18)	0.001
	Surface roughness	0.5 (0.11)	0.5 (0.10)	0.0 (-0.03, 0.05)	0.70 (18)	0.491

[a]Paired *t*-test

Table 5: Comparisons between groups after bleaching regime

Variables	Groups	*n*	Mean (SD)	*F* Statistics (df)[a]	*P*
Colour change after bleaching	Opalescence PF 15% (PB)	19	12.2 (4.07)	80.657 (2)	<0.001[c]
	Whitelight Tooth Whitening (WL)	19	12.2 (4.32)		
Difference in microhardness	Opalescence PF 15% (PB)	19	124.7 (200.00)[b]	-	<0.001[d,e]
	Whitelight Tooth Whitening (WL)	19	88.7 (174.67)[b]		
Difference in surface roughness	Opalescence PF 15% (PB)	19	0.0 (0.18) b	-	0.733[d]
	Whitelight Tooth Whitening (WL)	19	0.0 (0.06) b		

[a]ANOVA, [b]Median (IQR), [c]Two pair of groups have statistically significant difference by *Post-hoc* Scheffe Test: Control- Opalescence PF 15% ($P<0.001$) and Control- Whitelight Tooth Whitening ($P<0.001$). [d]Kruskal-Wallis Test (*H*-statistics). [e]Two pair of groups have statistically significant difference by Mann-Whitney Test: Control- Opalescence PF 15% ($P<0.001$) and Control- Whitelight Tooth Whitening ($P=0.001$)

hemoglobin. Red blood cells and hemoglobin pigments penetrate into the tooth structures to give more discriminative contrast in evaluation of superficial and in-depth action after application of different bleaching agents.[1] After blood staining procedure on the tooth samples, the colorimetric analysis showed that L* and b* values decreased, while a* value has no significant changes in all groups. The decrease in L* value for all groups shows that the sample became darker; meanwhile, the decrease in b* value shows that the yellowness of the sample is reduced compared to prestaining. This indicates that the samples were uniform and even result of staining was achieved to start with the bleaching regimen.

After bleaching, the L* value for PB and WL groups increased showing that the tooth became lighter. However, the b* value for PB group decreased, while WL group recorded an increase in b* value. This shows that the yellowness in PB group decreased, while for WL group, the yellowness of the tooth sample increased. The a* value for PB group decreased significantly showing that the bleaching agent worked to reduce the redness of the tooth sample. Although both bleaching agents recorded the same mean color changes of 12.2 after bleaching, the efficacy of PB% was slightly more apparent compared to WL as it not only managed to lighten the tooth, but also it reduced the yellowness and redness of the tooth sample, but statistically, both have the same efficacy compared to the control group and there is no statistical significance between the two groups.

This study revealed a significant increase in microhardness of tooth sample for both PB and WL groups after bleaching with PB group showing higher increment. However, these results contradict the study done by Lopes *et al.* that shows no alterations on enamel surface after application of 10% carbamide peroxide gel (Opalescence).[19] Study by Delfino *et al.* also revealed no changes in microhardness of bovine enamel after bleaching with 10% carbamide peroxide gel, 16% carbamide peroxide gel, and 6.5% hydrogen peroxide-based strips.[20] Microstructural alterations in bleached enamel may be reversed by the remineralization action of fluoride that is contained in the PB group (Opalescence PF 15%) which also further strengthens enamel. However, the increase in microhardness for WL group needs further investigation of whether or not it contains fluoride which has not been mentioned by the manufacturer.

None of the groups in this study showed the statistically significant difference for surface roughness after bleaching. However, the study conducted by Pinto *et al.* that used whiteness perfect 10% carbamide peroxide (10% CP), Colgate Platinum (10% CP), Day White 2Z (7.5% HP), Whiteness Super (35% CP), Opalescence Quick (35% CP), and Whiteness HP (35% HP) show that all groups increased in surface roughness ($P < 0.05$).[12] Pinto in his study used profilometer Surf-Corder SE 1200 (Kosaka Lab Ltd., Tokyo, Japan) with a measuring range of 520 μm vertically, 25 mm horizontally, vertical resolution of 0.008 μm, and measuring speed of 0.2 and 0.5 mm/s. The profilometer used in our study has a wider measuring range and speed; thus, it is more sensitive compared to the profilometer used by Pinto in his study. This shows that the minimal and nonsignificant changes of surface roughness observed in this study are legit.

This is an *in vitro* study, so the results obtained may subject to some differences as compared to *in vivo* studies due to the absence of clinical variables such as salivary components, oral cavity temperature, pH, continuous cyclic fatigue, and patient's diet.

Conclusions

With all the limitations in this study, it can be concluded that professional home bleaching agent showed similar efficacy, with no effect on surface roughness, and both caused an increment in microhardness. The changes observed for the microhardness of tooth sample after bleaching regimen in this study warrants additional investigation.

Acknowledgment

Mr. Mohd Yusoff Soon Abdullah, Mrs. Nora Aziz , Mr. Mohd Saiful Bahrin Mat Nasir, Mr. Fairuz Hasbullah, Mr. Mohamad Zulhelmi Mohd Nor from School of Dental Sciences, USM.

Financial support and sponsorship

This study was financially supported by USM Short Term Grant: 304/PPSG/61313102.

Conflicts of interest

There are no conflicts of interest.

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