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ABRASIVE VERSUS NONABRASIVE WHITENING TOOTH PASTES EFFICIENCY AND ENAMEL SURFACE ROUGHNESS (IN-VITRO STUDY)

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Abstract

Aim: This in vitro study was carried out to evaluate the efficiency of abrasive versus nonabrasive optical based whitening tooth pastes.
Methods: A total of 30 sound extracted bovine teeth were sectioned, mounted in acrylic block and randomly divided into 3 groups I-III (water (control), abrasive optical whitening tooth paste (Closeup Diamond Attraction), nonabrasive optical whitening tooth paste (Closeup White Now)) respectively. The buccal surface of each sample was flattened and stained by immersion into a concentrated tea solution. Then samples were subjected to 5500 double strokes of brushing with 200g force using a brushing simulator. Tooth color and surface roughness were measured before and after the brushing procedure using reflecting spectrophotometer regarding (CIE) and a contact profilometer surface roughness tester.
Results: For color, both whitening tooth pastes showed a statically significant means of ΔE1 and ΔE2 compared to the control group indicating a higher efficiency. Furthermore, all groups showed a statistically significant increase in roughness after brushing. On the other hand, they showed a non-statistically significant means compared to each other.
Conclusions: Both types of pastes were effective in teeth whitening without creating potential harmful to surface of enamel for a time equivalent to one year usage in oral cavity.

1. Introduction

Toothbrushing is the simplest and the most common daily oral hygiene measures. Tooth brushing offers a basic protection from plaque accumulation and dental caries. **[1, 2]** Many people use whitening tooth pastes for esthetic purpose. Tooth brushes and pastes should have almost no or little effect on enamel. However, incorrect oral hygiene habits can lead to increase damage to enamel**. [3, 4]**
Tooth pastes are defined as semi-solid materials used for removing deposits from teeth when used in combination with toothbrush. **[5, 6]** Whitening pastes have been introduced in aesthetic dentistry as they have a beneficial effect on extrinsic stain. The extrinsic stains usually are related to poor oral hygiene, smoking habits, chromogenic food and drinks such as tea and coffee. **[7-9]**
The effect of whitening toothpastes is based on three basic mechanisms. The first one is mechanical mechanism based on containing more abrasive agents than conventional pastes. The second one is chemical mechanism based on the presence of active chemical ingredients. **[10, 11]** The last one is optical mechanism based on deposition of thin semitransparent layer of blue covarine or blue sapphire pigments for masking yellowish color appearance.**[12]** Furthermore, using a combination of two or more of these mechanisms can be used for optimizing whitening effect.
Whitening tooth pastes work in conjunction with brush bristles to remove the outer layer of stained plaque without changing the color of teeth. **[5, 13]** The types and amount of toothpaste's abrasive particles and types of tooth brush should be considered as they may have harmful effect on oral soft and hard tissues. **[14, 15]** Preserving enamel surface smooth is very important property as increasing roughness can affect food, bacterial and plaque accumulation. **[16]** On the other hand, influencing factors like bacterial colonization and dental plaque development to surface roughness, incorrect oral hygiene measurements and dietary habits affect aesthetic appeal. **[17]**
Efficiency of whitening tooth pastes have received significant scientific interests. Previous studies showed that whitening tooth pastes could have variable effects on color and roughness of enamel ranging from low to high**. [15, 18-25]** For that, this study was conducted to evaluate the effect abrasive and nonabrasive based optical whitening tooth pastes on color and surface roughness of enamel. The research hypothesis of this study was that the abrasive based optical whitening tooth pastes has a higher effect on improving color and increasing roughness more than the nonabrasive one. The null hypothesis was that both types of whitening tooth pastes have the same effect on color and roughness.

Materials and Methods

Ethical consideration

This study was approved by ethics committee of faculty of dentistry, Minia University RHDIRB2017122004 under the

protocol number (362), 2019. All steps of the study were caried out regarding to this protocol.

Grouping and Samples preparation

A total of 30 sound bovine incisors free from stains, with matched shade, size, and surface texture were used in this study. Teeth were cleaned and stored in 0.1% buffered thymol solution at 4◦C up to 2 months.

The coronal portion of each tooth was sectioned approximately 2 mm below cement-enamel junction under copious amount of water coolant. The crowns were mounted into acrylic resin blocks of (50 mm x30 mm x10 mm) and the labial surface was adjusted 2- 3 mm above and parallel to the base of the block. **[8]** The samples were labeled and randomly divided into 3 groups (n=10). Group Ⅰ water (control), Group II abrasive optical whitening tooth paste (Closeup- white now), Group III nonabrasive optical whitening tooth paste (Closeup – diamond attraction). The materials, brand name, description, manufacturer, ingredients and batch number of tooth pastes were represented in (Table 1)

Table (1): materials used in this study

Brand Name	Description	Manufacturer	Ingredients	Batch Number
Closeup Diamond Attraction	Gel (Abrasive optical whitening tooth paste)	Unilever - Mashreq Under License From Unilever PLC. England	Sodium-monofluorophosphate(1450ppm), potassium citrate, zinc citerate, Sorbitol, Aqua, hydrated silica (HS), Sodium Lauryal Sulphate (SLS), Aroma (Flavor), hydroxyapatite, cellulose gum (CG), sodium saccharin (SS), trisodium phosphate (TSP), glycerin, sodium hydroxide, PEG-32, tocopheryl acetate, mica, limonene,blue covarine	B08
Closeup White Now	Paste (Nonabrasive optical whitening tooth paste)	Unilever - Mashreq Under License From Unilever PLC, England	Sodium fluoride (1450ppm Flouride), sorbitol, aqua, HS, SLS, aroma, CG, SS, TSP, glycerin, poly vinyle methyle ether and maleic acid (PVM/MA) copolymer, PEG-32, lecithin, mica, limonene, blue sapphire pigments	B37

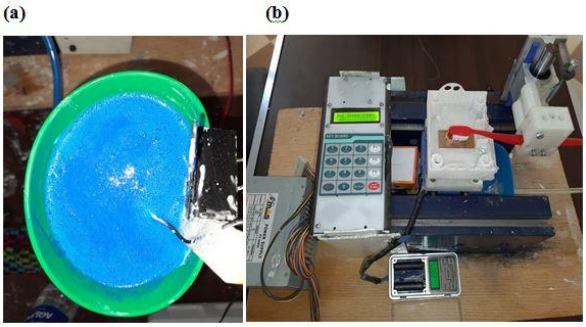
The labial surfaces of samples were grounded to be flattened using an Aluminum oxide fine grit grinding wheel (STECO grinding wheel, AO grit 46, 8x1x1, China) with low-speed motor under water coolant. After that the samples were finished using 800, 1000 grit Aluminum oxide abrasive papers (Latexed waterproof AO paper, electro coated, ORIENTCRAFT, China). Then polished using a slurry of fine talc to obtain standardized surface for investigation. At the end the samples were cleaned in an ultrasound water bath (Ultrasonic cleaner UK-, VGT- 800, China.) for 15 minutes.

Staining and brushing procedures

For staining procedures were carried out regarding to **Vaz et al., 2019. [26]** A concentrated tea solution was prepared by adding 16g of tea in 500ml of boiling water, filtered after 5 minutes and left to be cool. Each sample was immersed in 50ml of prepared solution for 18h followed by 6h of drying for 4 days. **[26]** A fresh slurry of 1:1of tooth paste to water was prepared be used in this study.

A custom-made unidirectional tooth brushing simulator (Brushing simulator, medical engineering department, faculty of engineering & precision measurement unit, bio-material department, faculty of dentistry, Minia University) was used to simulate the manual brushing process. The machine was adjusted to apply 5500 double strokes in forward and backward direction with a speed of 60 cycle/min and a load of 200 ± 20g (2N) and continuous flow rate 3ml/min of the slurry to simulate a total of 1year of tooth brushing regarding **Turssi et al., 2019, Liporoni et al., 2020 and Schwarzbold et al., 2021. [27-29]** A medium brush (Fushs-Silver comfort Tooth Brushes**,** Swiss Egyptian Co. (Sesic), P.O.4-050521 (15081)) with flat trimmed bristles was fixed to the machine. The brush was replaced every 1375 cycles which equal to 3 months of brushing as recommended by American dental association (ADA). **[30]** (Figure 1) At the end of brushing cycles, each sample was washed with running water and ultrasonically cleaned.

Fig (1): (a) slurry of whitening tooth paste (b)Toothbrush fixed to the brushing simulator before adding slurry



Color measurements

The color of each sample was measured 3 time, before staining and brushing (T0), after staining and before brushing (T1) and after brushing (T2) using reflecting spectrophotometer (VITA Easy shade® V, VITA Zahanfabrik H. Rauter Gmbh & Co.KG, Bad Säckingn, Germany).

The Color measurements were carried out according to three coordinate values (L*, a*, b*), as recommended by Commission International de l'Eclairage (CIE). For each sample the color measurements were carried out 3 time and the mean value of (L*, a*, b*) were recorded as reading of the sample. The color difference between measurements was calculated using the following equation:

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

Where,

ΔE = color difference

ΔL* = the value or degree of lightness

Δa* = the degree of red/green color (+a: red, -a: green)

Δb* = the degree of yellow/blue color (+ b: yellow, - b: blue)

Surface roughness measurement

The surface roughness was measured using a contact profilometer surface roughness tester (Mitutoyo Surf Test SJ 210, Mitutoyo Corp, Japan). The first measurement was done after staining and before brushing recorded as initial reading (IR) and repeated again after brushing recorded as final reading (FR). Four readings per sample were recorded, 2 in the direction of brushing and 2 perpendiculars to this direction. The mean of the 4 tracing of every sample was calculated and recorded as the value of roughness (nm) of the sample.

Statistical analysis

Data were collected and statistically analyzed using SPSS (Statistical Package for Social Sciences) version 18. P-values ≤ 0.05 were considered significant.

Results

color measurement

Regarding color parameters L*, a* and b*. All groups showed statistically significant decrease in mean values of (L*) after staining. Both group II and group III showed a statistically significant increase in mean values of (L*) after brushing. All groups showed a statistically significant increase in mean values of (a*, b*) after staining. Both group II and group III showed a statistically significant decrease in mean values of (a*, b*) after brushing. L*, a* and b* for T0, T1and T2 for each group were presented in (Table 2, Figure 2,3,4).

Table (2): Means and standard deviation values of color parameters (L*, a*, b*)

Groups	parameters at baseline (T0)			Parameters after staining(T1)			Parameters after brushing(T2)			P value		
	L*	b*	a*	L*	b*	a*	L*	b*	a*	L*	b*	a*
Group I (control)	82.56^{A} ±2.04	31.86^{A} ±2.59	2.02^{A} ±0.53	51.58^{B} ±1.41	44.43^{B} ±2.08	14.71^{B} ±0.06	53.56^{b,B} ±0.82	41.95^{bA,B} ±2.13	13.24^{b-B} ±0.67	0.00*	0.008*	0.000*
GroupII (Closeup - diamond attraction)	82.86^{A} ±2.51	34.49^{A} ±1.86	1.94^{A} ±0.3	51.93^{B} ±1.04	44.88^{B} ±1.54	13.68^{B} ±1.12	76.473^{a,C} ±2.19	38.13^{a-C} ±1.46	4.666^{a,C} ±1.03	0.00*	0.000*	0.000*
GroupIII(Closeup - white now)	83.02^{A} ±2.7	33.91^{A} ±2.5	1.76^{A} ±0.41	51.82^{B} ±1.17	42.87^{B} ±3.78	13.64^{B} ±2.17	73.366^{a,C} ±2.63	37.42^{a-C} ±1.22	6.35^{a,C} ±1.16	0.00*	0.001*	0.000*
P values between groups	0.952ns	0.221ns	0.8737ns	0.897ns	0.473ns	0.445ns	0.00*	0.027*	0.00*			

Significance level p≤0.05, *significant, ns=non-significant

For each parameter within the same row, means sharing the same capital superscript letter are not significantly different

For each parameter within the same column, means sharing the same small superscript letter are not significantly different

Fig (2): Bar chart illustrates the means of L* at T0, T1 and T2

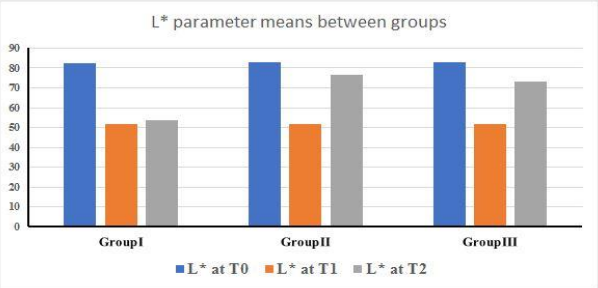


Fig (3): Bar chart illustrates the means of b* at T0, T1 and T2

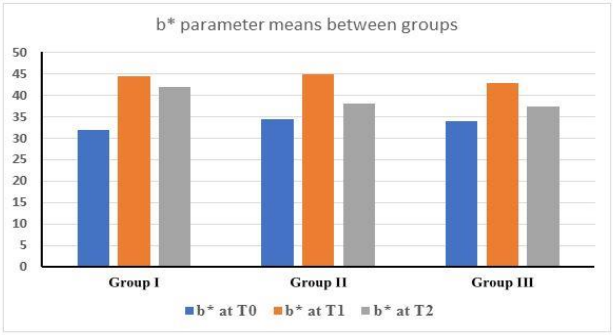
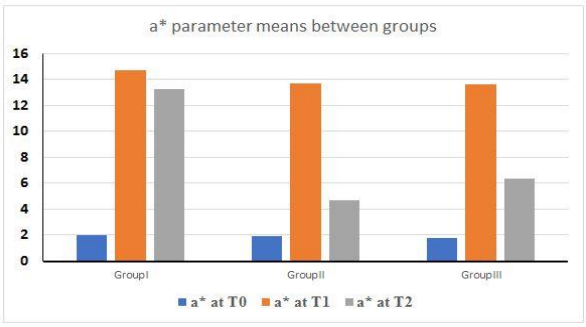


Fig (4): Bar chart illustrates the means of a* at T0, T1 and T2



Within all tested groups the color change means values ΔE0 from (T0 to T1) were statistically non-significant. The color changes between T1 to T2 (ΔE1) means were statistically significant between all groups. Both group II and group III showed a higher statistically significant means of color change (ΔE1) than group I. Furthermore, the color changes ΔE2 between (T2 to T0) means of group I were statistically higher than group II and III. Means and standard deviation (SD) of ΔE0, ΔE1 and ΔE2 were presented in (Table 3, Figure 5)

Table (3): Means and standard deviation values of (ΔE) for comparison between 3 groups

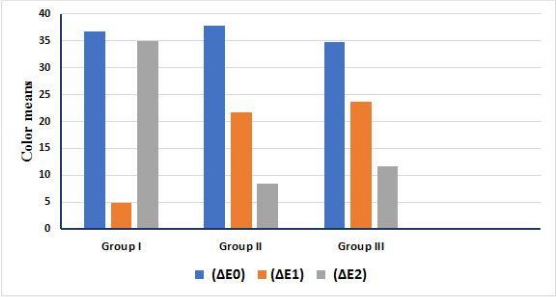
Groups	Color		
	ΔE0	ΔE1	ΔE2
Group I (control)	36.635^{a,A} ±2.61	4.847^{b,B} ±0.75	34.842^{a,A} ±2.85
Group II (Closeup - diamond attraction)	37.782^{a,A} ±2.5	21.75^{a,B} ±2.53	8.539^{b,C} ±2.79
Group III (Closeup - white now)	34.795^{a,A} ±1.84	23.605^{a,B} 7±1.84	11.621^{b,C} ±3.509
P values between groups	0.386ns	0.00*	0.00*

Significance level p≤0.05, *significant, ns=non-significant

Within the same column, means sharing the same small superscript letter are not significantly different

Tukey's post hoc test: within the same row, means sharing the same capital superscript letter are not significantly different

Fig (5): Bar chart illustrates the means of (ΔE0), (ΔE1) and (ΔE2) with different groups



Surface roughness test

Within all tested group IR and FR means were statistically non-significant between groups. However, for each group FR was statistically significantly higher than IR. Furthermore, the percent change of surface roughness means of all groups were non-statistically significant. Means, standard deviations and percent change of surface roughness were presented in (Table 4, Figure 6,7)

Table (4): Means and standard deviation of initial roughness (IR), final roughness (FR) and percentage change (%)

GROUPS	Surface roughness (nm)		P value between IR and FR	Percentage change (%) from IR to FR
	IR	FR		Mean ± SD
	Mean ±SD	Mean ± SD		
Group I (control)	27.03 $^{A.}$ ± 0.88	35.178^{B} ±4.30	0.027*	30.09 ±13.79
Group II (Closeup - diamond attraction)	27.15 ^{A} ±0.39	37.71^{B} ±3.35	0.001*	38.83 ±11.41
Group III (Closeup - white now)	27.072^{A} ±4.03	39.44^{B} ±9.39	0.008*	44.20 ±15.89
P values between groups	0.538ns	0.582ns		0.335ns

Significance level p≤0.05, *significant, ns=non-significant

Within the same column, means sharing the same small superscript letter are not significantly different

Within the same row, means sharing the same capital superscript letter are not significantly different

Fig (6): Bar chart illustrates the initial and final surface roughness means

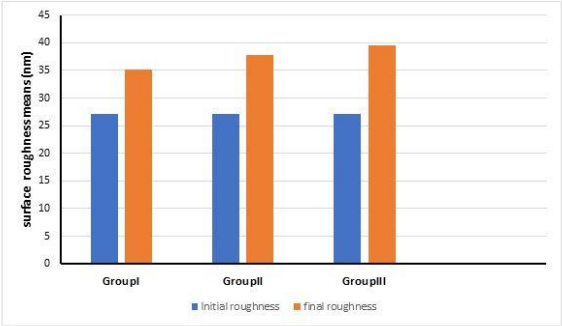
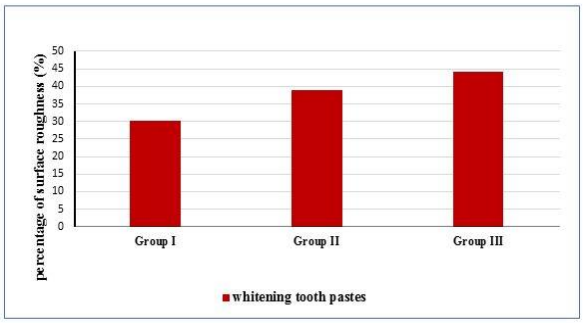


Fig (7): Bar chart illustrates the means percentage change of surface roughness (%) between groups



Discussion

People seek to get white and bright teeth as teeth are important factors contributes aesthetic appearance of the face. **[31]** For that reason, dentists are interested in cosmetic dentistry. Especially that, the teeth whitening which become a necessary component to enhance dental aesthetics. **[11]**

Smoking habits, food and drinks like tea and coffee that contain chromogenic stains are form the main causes of teeth discoloration. **[13]** On the other hand, rough enamel surface can induce bacterial adhesion, plaque accumulation, stain adsorption to teeth surface. Furthermore, it can cause diffuse reflection of the light on the teeth causing dull appearance that interfere with the aesthetic. **[32]** For these reasons, this study was conducted to determine the whitening efficiency of abrasive optical based whitening paste (Closeup -diamond attraction) and nonabrasive optical based whitening paste (Closeup - white now) and their effect on surface roughness of enamel.

Enamel is normally exposed in the oral cavity and contributes most to the aesthetic appearance of human teeth. Bovine teeth were used instead of human teeth due to availability and their enamel chemical composition and structure are comparable to those of human teeth **[33]**. Furthermore, bovine teeth anatomy gives larger flat areas on its labial surface comparable to human teeth giving more accurate reading for color and roughness.

In order to standardize brushing process regarding technique, force, duration and frequency of brushing, a customized unidirectional brushing simulator was constructed regarding to **Bizhang et al., 2017 and Athawale et al., 2018 studies**. **[18, 34]**.

Regarding ΔE1 results which represents the difference between T2 and T1, the highest mean recorded for group III followed by group II. Moreover, the means of both groups were statistically significant to group I (control) indicating the whitening effect of both groups compared to control group. This agreed with results

Awdah et al., 2017 and Shamel et al., 2019 and could be explained by the presence of blue covarine and blue sapphire in the tooth past component of group II and III respectively. **[15, 35]** Both stains are able to deposit a translucent layer of the blue pigment on the surface of enamel. **[23]** This was determined by a statistically significant reduction of b* parameter of both groups after brushing (T2). As known blue is the complementary color of yellow in the color wheel hence a change to blue produces a whiter appearance by masking the yellowish staining produced by immersion in tea. **[26, 36, 37]** Another observation from this study was that group II and III showed lower statistically significant mean of ΔE2 compared to group I indicating that both groups had efficient whitening effect compared to the control.

These whitening efficacy of tooth pastes result might be against other studies that showed the blue covarine and blue sapphire containing whitening tooth pastes had no whitening or no significant alteration of L*, b* and ΔE of teeth. **[20, 38, 39]** This probably explained by difference in brushing technique and shorter period of the brushing with different concentration of pastes slurry. All these factors might cause in adequate deposition of blue transparent layer. Group II and III showed a statistically non-significant means for ΔE1 and ΔE2 despite group II had a high abrasive as claimed by manufacturer. This could be explained by containing too fine abrasive particles less than 4μm that couldn't remove stains. This finding was in conduct with **Aspinall et al., 2021. [5]**

It was worthy to mention that the brushing process with water without paste in control group had no effect on the stain as confirmed by a non-significant change in L*, b* and a* between T1 and T2 of group I.

Regarding to surface roughness test results, all investigated groups showed a statistically significant increase in surface roughness after brushing. On the other hand, all groups showed a statistically non-significant means to each other. This could indicate that the flat end medium tooth brush bristles played the main role in changing enamel surface roughness. These results were concurrent with previous studies findings **[15, 21, 40]**. Other studies reported that brushing with water had no significantly increase surface roughness and brushing with tooth pastes provoked roughness compared to water. **[41, 42]** That might be explained by the difference in brushing technique, brush bristle type and stiffness which could retain more amount of paste against the tooth surface for larger period. **[43]**

It should be pointed that the mean value of surface roughness for all group after brushing did not exceed than the maximum acceptable clinical threshold value of roughness 200 nm (0.2μm) **[7]**. Finally, the null hypothesis was accepted regarding color and surface roughness results.

Conclusion

This in vitro study focused on assessment the efficacy of abrasive and non-abrasive optical whitening tooth pastes accompanied with medium brush bristles on surface roughness. Within the limitation of this study, both types of pastes were effective and safe for whitening the teeth without creating potential harmful effect on surface roughness of enamel up to one year usage in oral cavity.

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