Effect of Whitening Toothpastes and Brushing on Microhardness of Esthetic Restorative Materials

Fouad Salama*/ Faika Abdelmegid**/ Lamya Alhomaidhi***/ Sara Alswayyed****/ Shatha Alfarraj*****

OBJECTIVE: *Whitening toothpastes are widely used. Hence, it is important to understand their effect on the surface properties of restorative materials. To evaluate the effect of three over-the-counter whitening toothpastes and toothbrushing simulation on microhardness of three restorative materials.* ***Study design:*** *Forty cylindrical (10x2mm) specimens were prepared from each restorative material and randomly assigned into four groups/10 each according to the whitening toothpastes used and distilled water (control). All specimens were measured for microhardness (Baseline–T1). The specimens were brushed with a soft brush using an in vitro tooth-brushing simulator with the assigned whitening toothpaste using the same setting for brushing cycles/load for all groups. Specimens were then measured for microhardness (T2) similar to baseline.* ***Results:*** *The highest (mean±SD) microhardness after application of the whitening* toothpastes *and brushing was recorded for Intense White and Filtek Z250 XT (127.6±1.8), followed by Optic White and Fuji ll LC (73.9±0.9) and Optic White and Photac Fill (72.7±1.3). There was statistically significant difference for microhardness between pre- and post-application of the whitening* toothpastes *and brushing for all tested restorative materials (P=0.0001). The microhardness of Filtek Z250XT with 3D White post-application of the whitening* toothpastes *and brushing was lowest compared to other* toothpastes and control *(P=0.0001).* ***Conclusion:*** *Microhardness increased after application of the whitening* toothpastes *and toothbrushing simulation for all combination of tested restorative materials and whitening* toothpastes. *The microhardness of FIiltek Z250XT with 3D White post-application of the whitening* toothpastes *and brushing was lowest compared to other* toothpastes and control.

Keywords: *Whitening* toothpastes*, Microhardness, Restorative Materials,, Bleaching*

INTRODUCTION

Currently the desire for whiter teeth is rapidly increasing among dental patients as people are being more aware of the color of their teeth.[1,2] Moreover, previous investigations revealed that many dental patients are unsatisfied with their smile and the color of their teeth.[3,4] Teeth bleaching has become a popular procedure ever since it was first introduced to the dental practice.[5] It is a very effective yet conservative treatment option for discolored teeth in comparison to other restorative treatment approaches as composite fillings, veneers or crowns.[6] As a result, many companies have competed to provide the market with different agents and methods for teeth bleaching.[7,8] Such products range from customized bleaching trays with bleaching gels, mouth-rinses, whitening strips, and toothpaste.[7-9] Whitening toothpastes are readily available over the counter, reaching to over 50% of the over the counter teeth bleaching products and the global marketplace where sales of whitening toothpastes alone exceeded \$3.2 million in 2016.[7-13] Whitening toothpastes are very handy to use because of their low-cost and easy access without the need for a professional prescription or supervision.[14] Whitening toothpastes are effective in reducing and removing stains.[8,9,15] They rarely contain hydrogen peroxide as

*Fouad Salama, Professor, Pediatric Dentistry, School of Dentistry, University of Detroit Mercy, USA. Former Professor Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.
**Faika Abdelmegid, Former Professor, Department of Oral Medicine and Diagnostic Sciences, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia.
***Lamya Alhomaidhi, Dental Intern, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia.
****Sara Alswayyed, Dental Intern, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia.
*****Shatha Alfarraj, Dental Intern, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia.

Send all Correspondence to:
Fouad Salama
Professor Pediatric Dentistry
School of Dentistry,
University of Detroit Mercy, USA
E-mail: salamafs@udmercy.edu

a bleaching agent or any of it is precursor products, the effect is usually achieved by mechanically abrasive particles found in their formulation such particles are silica, dicalcium phosphate, dihydrate and alumina that promote stain removal.[16-19]

Dental restorations are susceptible to alteration when subjected to different environmental conditions in the oral cavity.[20] The change of physical properties of a restoration impact its clinical durability.[20,21] PermaFlo (UltradentSurface roughness and microhardness are one of the important markers to evaluate the clinical success of restorations because plaque accumulation, discoloration, gingival irritation, and secondary caries may be observed more on rough restoration surfaces.[8,9,15,22] One of the important factors for any restorative material for its longevity is the microhardness.[23] As long as the hardness is linked to material's strength and rigidity[24] it has a strong effect on the clinical durability of restorations.[25] Surface microhardness has been used to measure the polymerization adequacy as an indirect method[26] for its simplicity and for presenting good association to the degree of polymerization.[27,28] With low surface hardness the restoration will be vulnerable for scratches and aggravate failure of restorations.[29] An ideal whitening toothpaste should only remove unwanted stains and deposits with minimal effect on tooth structure and restorations.[18,19] However, teeth bleaching agents can alter the surface properties of the tooth structure as well as restorative materials.[1] Thus, the effect of teeth bleaching on different types of esthetic tooth-colored restorations must be considered as dental patients requiring teeth bleaching may have different kinds of fillings.[1]

There is concern about the effect of whitening toothpastes on restorative materials.[30-34] Therefore, the purpose of this study was to evaluate the effect of three over-the-counter whitening toothpastes and toothbrushing simulation on microhardness of three restorative materials. The null hypothesis was no difference in microhardness of the tested restorative materials after application of whitening toothpastes and toothbrushing simulation.

MATERIALS AND METHOD

Three restorative materials were used in this study: A nanohybrid resin composite (Filtek™ Z250 XT, 3M ESPE, MN, USA), resin modified glass ionomer (Photac™ Fil Quick Aplicap™, 3M ESPE, MN, USA), and light-cured resin reinforced glass ionomer (GC Fuji II LC®, GC America Inc., Alsip, IL, USA). The power sample size was 0.81 and level of significant σ =0.05 with estimated standard deviation = 0.9, the sample size should be at least 9 in each group. The three whitening toothpastes used in this study are presented in Table 1. Forty specimens (10 x 2 mm) from each restorative material were prepared using silicon Teflon mold and used in this study. The mold was placed on a transparent matrix strip and glass slide, and then the different restorative materials were inserted and packed into the mold. The filled mold was covered with a second transparent matrix and glass slide; light pressure was applied to expel excess material from the mold. Where applicable each specimen was polymerized according to the instructions of the manufacturers using an LED curing light (Bluephase®, Ivoclar Vivadent, Schaan, Liechtenstein). The light cured disk was then flipped and the bottom of the specimen was polymerized to ensure complete polymerization. The specimens were stored in distilled water at 37°C for 72h. Specimens were polished sequentially with 240, 320, 400, and 600 silicon carbide paper under running water and final polish using Sof-Lex discs (3M ESPE, MN, USA). After that, specimens were stored in distilled water for 72h at 37°C and then were thermocycled (Thermocycler SD Mechatronik, GmbH Dental Research Equipment, Germany) 1500 times cycles in baths at 5°C and 55°C, with 5 seconds transfer time and 30 seconds dwell times. The 40 specimens prepared from each material were randomly assigned to 4 groups of 10 each according to the assigned whitening toothpastes and distilled water (control). Following the allocation of the specimens, the surface microhardness was measured using a microhardness testing machine (Baseline–T1). The specimens were brushed with a soft brush (TARA Special, Tara Toothbrush Company LLC, Dammam, Saudi Arabia) with the assigned whitening toothpaste using an *in vitro* Toothbrush Simulation ZM-3 (SD Mechatronik GMBH, Feldkirchen-Westerham, Germany) using the same setting for brushing cycles and load. The surface of each specimen was submitted to 10,950 brushing cycles (200 g load, 0.98 N) equivalent to 1,620 minutes. Specimens were then measured for microhardness (Post exposure–T2) similar to baseline. Microhardness measurements were done using a Vickers diamond indenter (Innovatest, Micro Vickers tester, Micro-Met II, BUEHLER, IL, USA) with a 200 g load applied for a duration of 15 seconds. The indentations were measured by a built-in graduated microscope with x40 objective lens. Three indentations were made for each specimen.

Table 1. The three whitening toothpastes used in this study and their ingredients

Whitening Toothpastes	Ingredients
Aquafresh IntenseWhite (GlaxoSmithKline plc. Middlesex, UK)	Aqua Sorbitol Hydrated silica Glycerin Pentasodium triphosphate PEG-6 Alumina Sodium lauryl sulfate Aroma Xanthan gum Cocamidopropyl betaine Titanium dioxide Condrus crispus (carrageenan) Sodium fluoride Sodium saccharin Sodium hydroxide Limonene CI 73360 CI 74260 CI 74160 Contains sodium fluoride (1450 ppm F)
Crest 3D White (The Procter & Gamble Company, Cincinnati, OH, USA)	Sodium Fluoride (0.15% W/V Fluoride Ion) (0.243%) Water, Sorbitol, Hydrated Silica, Disodium Pyrophosphate, Sodium Lauryl Sulfate, Flavor, Cellulose Gum, Sodium Hydroxide, Sodium Saccharin, Carbomer, Mica, Titanium Dioxide, Blue 1
Colgate Optic White (Colgate-Palmolive Company, New York, NY, USA)	Active Ingredient: Sodium Monofluorophosphate. Inactive Ingredients: Propylene Glycol, Calcium Pyrophosphate, Glycerin, PEG/PPG 116/66 Copolymer, PEG-12, PVP, Silica, Flavor, Sodium Lauryl Sulfate, Tetrasodium Pyrophosphate, Hydrogen Peroxide, Disodium Pyrophosphate, Sodium Saccharin, Sucralose, BHT

Statistical analyses were performed using paired t-test and ANOVA to compare microhardness between pre- and post- exposure to the assigned whitening toothpastes and control as well as brushing using tooth-brushing simulator for all restorative materials. All statistical analyses were set with a significance level of $P<0.05$. The statistical analysis was performed using SPSS Version 20 (Statistical Package for the Social Science; SPSS Inc, Chicago, IL, USA).

RESULTS

Means and standard deviations of microhardness for each restorative material and whitening toothpaste at baseline and post-treatment is presented in Table 2. The means for all whitening toothpastes with different restorative materials were almost same at baseline. While the means for all whitening toothpastes with different restorative materials showed increase of microhardness post-treatment. The highest (mean±SD) microhardness after application of the whitening toothpastes and brushing was recorded for Intense White and Filtek Z250 XT (127.6±1.8), followed by Optic White and Fuji ll LC (73.9±0.9) and Optic White and Photac Fill (72.7±1.3).

To find out differences between pre- and post-treatment for all whitening toothpastes, paired t-test was performed, where statistically significant difference between pre- and post-treatment for all whitening toothpastes was found (Table 3). The mean results for the post-treatment were higher than baseline for all whitening toothpastes (P<0.05).

To find out differences between pre- and post-treatment for all restorative materials, paired t-test was performed, where statistically significant difference between pre- and post-treatment was found for all restorative materials (Table 4). The mean results for the post-treatment were higher than baseline for all restorative materials (P<0.05).

To find out differences between whitening toothpastes according to restorative materials based on baseline and post-treatment, ANOVA test was used. The results showed statistically significant difference between Optic White, 3D White, Intense White, and control groups at baseline (Table 5). The 3D White mean result was highest at baseline (P≤ 0.05) with FIiltek Z250XT. However, the mean results for post-treatment for 3D White was lowest compared to the other whitening toothpastes (P≤ 0.05) with FIiltek Z250XT. On the other hand, 3D White mean results were lowest in baseline level (P≤ 0.05) with Photac Fill, and mean results for post-treatment for control group was lowest compared to other whitening toothpastes (P≤ 0.05) with Photac Fill. No significant differences between groups in baseline for Fuji II LC (P≤ 0.05). While post-treatment for Fuji II LC, the mean results was lowest among control group (P<0.05).

The 3D white showed the least impact on microhardness among all tested restorative materials compared to the other whitening toothpastes. Photac Fill and Fuji II showed the highest increase of microhardness when brushed with Optic White. However, the highest change of Filtek Z25 XT was observed when brushed with Intense White.

Table 2. Mean and standard deviation of microhardness for each restorative material and whitening toothpaste at baseline and post-treatment.

Whitening Toothpastes	Restorative Materials					
	Filtek Z250 XT		Photac Fill		Fuji II LC	
	Baseline Mean (SD)	Post Treatment Mean (SD)	Baseline Mean (SD)	Post Treatment Mean (SD)	Baseline Mean (SD)	Post Treatment Mean (SD)
Optic White	107.3 (0.8)	117.3 (1.2)	46.4 (0.4)	72.7 (1.3)	56.5 (0.4)	73.9 (0.9)
3D White	107.8 (0.7)	109.6 (1.7)	46.3 (0.4)	60.0 (1.3)	56.4 (0.5)	60.5 (0.9)
Intense White	107.4 (0.6)	127.6 (1.8)	46.6 (0.6)	70.3 (2.0)	56.5 (0.4)	67.9 (1.2)
Distilled Water (Control)	107.5 (0.7)	112.5 (2.0)	46.8 (0.6)	46.7 (0.8)	56.6 (0.4)	57.2 (0.9)

Table 3. The mean and standard deviation of difference of microhardness between pre- and post-treatment for all whitening toothpastes

Whitening Toothpastes	Baseline		Post Treatment		P-value
	Mean	SD	Mean	SD	
Optic White (n=90)	70.10	26.81	87.95	20.89	0.0001*
3D White (n=90)	70.16	27.07	76.70	25.54	0.0001*
Intense White (n=90)	70.18	26.786	88.58	27.79	0.0001*
Control (n=90)	70.28	26.77	72.13	29.06	0.0001*

*Significant

Table 4. The mean and standard deviation of difference of microhardness between pre- and post-treatment for all restorative materials

Restorative Materials	Baseline		Post Treatment		P-value
	Mean	SD	Mean	SD	
Filtek Z250 XT (n=120)	107.50	0.69	116.74	11.25	0.0001*
Photac Fill (n=120)	46.53	0.53	62.42	10.40	0.0001*
Fuji II LC (n=120)	56.52	0.48	64.87	6.58	0.0001*

*Significant

Table 5. The means and standard deviations of difference of microhardness between pre- and post-treatment according to all restorative materials and whitening toothpastes

Restorative Materials	Time	Optic White (n=30)		3D White (n=30)		Intense White (n=30)		Control (n=30)		P-value
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Filtek Z250 XT	Baseline	107.34	0.79	107.77	0.66	107.41	0.61	107.50	0.66	0.083
	Post-treatment	117.29	1.22	109.61	1.78	127.56	1.77	112.51	2.01	0.0001*
Photac Fill	Baseline	46.46	0.44	46.28	0.37	46.63	0.56	46.78	0.61	0.001*
	Post-treatment	72.71	1.32	60.00	1.25	70.29	1.99	46.68	0.76	0.0001*
Fuji II LC	Baseline	56.54	0.44	56.44	0.45	56.50	0.62	56.57	0.39	0.762
	Post-treatment	73.86	0.92	60.49	0.94	67.89	1.20	57.22	0.870	0.0001*

*Significant

DISCUSSION

The null hypothesis of the present study was rejected, as there was difference in microhardness of the tested restorative materials after application of whitening toothpastes and toothbrushing simulation. It is known that whitening dentifrices used during tooth brushing act to decrease plaque and surface deposits on teeth as well as help in removing stains and discolorations.[19] Moreover, it has been reported that some ingredients found in over-the-counter toothpastes could impact the surface properties of tooth structure as well as restorative materials.[4,8,22,35] Abrasives found on toothpaste and toothbrush bristles may deteriorate restorative material and tooth surfaces by producing superficial imperfections, scratches, and micro wear.[23] As the demand for whiter teeth is rapidly increasing which led to the wide verity of different whitening toothpastes available in the market.[36] More studies are needed to report the effect of whitening toothpastes on surface properties of esthetic restorative materials.

Restorative material hardness is a characteristic used to measure the ability of a material to withstand penetration and deformation when subjected to a specific load on its surface with an indenter.[29] Microhardness is a critical property in the dental practice as it is a strong indicator of the clinical deterioration of dental materials.[37] It also correlates to the strength and rigidity of restorative materials.[24] Vickers microhardness test was used in this study which is a valuable test to measure a material's microhardness.[24] In the present study, three whitening toothpastes (3D White, Intense white and Optic white) were used to evaluate their influence on the surface microhardness of three different restorative materials. Soft toothbrushes were used to minimize the possible effects in the experiment as recommended in another study.[32]

The Filtek Z250 XT resin composite showed the highest mean values of Vickers microhardness (127.6). Probably their increased microhardness is related to the nanoparticle size of inorganic filling, because Filtek Z250 XT is considered as nanohybrid resin that can display better mechanical properties than the others tested restorative materials. Previous reports have revealed that the Vickers microhardness values of another nanohybrid resin composite are from 74.9 to 97.68 Vickers microhardness.[38,39] One of the factors that influence the decrease of resin composite hardness is the depth of cure of resins, it can be affected by several factors associated with the source of light polymerization, including the spectral emission (wavelength distribution), light intensity, exposure period, and irradiation distance.[38,40,41] Among these factors, the irradiant rate of light given out by different light-curing units and the light-curing times. Depth of cure for light-activated dental composites has often been evaluated by the measurement of the hardness of the material at specific depths.[40] Similar to our results, a study reported that nanohybrid resin composite has the highest mean values of Vickers microhardness.[4,42]

In this study, we found that specimens showed significantly different microhardness values which may be related to their different composition. These results are similar and comparable to the data reported in other studies.[38,42] A study reported a linear correlation between microhardness and specimen depth of polymerization regardless of the resin composite used the investigators concluded that the energy of lamps is essential for successful curing of all the composite resins.[38] In general, a higher degree of conversion correlates with greater hardness.[43] It is difficult to distinguish the effect of the compositions of restorative materials including filler size and shape on their mechanical properties, and the filler load is the main factor for determining elastic modulus properties, while filler size and shape should be considered as secondary factors for altering material properties.[42] Nevertheless, the different indentation force such as lower *Vickers microhardness* values can be attributed to variations in test parameters as per reported by other authors.[44]

The current whitening methods are analyzed and discussed from a chemist's viewpoint. Frequently used whitening agents are abrasives (mechanical removal of stains), antiredeposition agents (prevention of deposition of chromophores), colorants (intended to lead to a white color), proteases (degradation of proteins), peroxides (oxidation of organic chromophores), and surfactants (removal of hydrophobic compounds from tooth surface).[8] Previous investigations of this topic reported conflicting results.[1] The results of this study showed statistically significant difference of microhardness between pre- and post-treatment with the whitening toothpastes and brushing for all tested whitening toothpastes and restorative materials (P=0.0001). The resin composite (Filtek Z250 XT) groups showed significant increase of microhardness after application of the tested whitening toothpastes compared to baseline. When Intense White and Optic White toothpastes were used, the microhardness increased significantly compared to resin composite treated with 3D White toothpaste and distilled water. This result contradict with the results of other studies where investigators found that whitening toothpastes reduce the microhardness and increase the roughness.[19,33,45,46] This difference was related to the different concentration of bleaching material used.[47] However, another study reported that 10% carbamide peroxide with over-the-counter whitening agents did not increase the whitening effect nor microhardness.[15] Our results also contradict with other studies, which reported decrease in the microhardness of restorative materials subjected to whitening toothpastes, this can be attributed to the different kinds of restorative materials and applied toothpastes, differences in the time and frequency of treatment, and difference in the study methods. A study evaluated the effect of bleaching with carbamide peroxide agents at concentrations of 10% and 21% on the microhardness of nano resin composite and nanohybrid resin composite concluded that there was a significant reduction in the microhardness of restorative materials observed after exposure to carbamide peroxide under a clinically simulated bleaching regimen.[47] In addition, the microhardness of nanohybrid resin composite was better than the nano resin composite. This finding supports the excellent performance of the nanohybrid resin composite used in our study in comparison to other restorative materials tested.

A study assessed the influence of whitening toothpastes on the surface roughness of a nanohybrid resin composite concluded that none of the whitening toothpastes evaluated were able to significantly increase the surface roughness of the nanohybrid resin composite in a short period (1 month).[45] Another study tested the microhardness of compomer restorative material and found that the effect of whitening toothpaste on microhardness is time and material dependent, as they found a difference in the reduction of microhardness over time.[23] A study tested microhardness of Silorane resin composite after bleaching and found that the microhardness was not altered, they reported that this result was expected because of the high chemical stability and hydrophobicity of Silorane matrix.[17] The possible explanation for this finding may be the softening effect of the hydrogen peroxide on the resin matrix.[17] After bleaching, oxidation reaction can occur in polymer chain of the resin matrix; and it is responsible for a more reduced microhardness for the material containing greater resin matrix.[17] In this study the light-cured glass ionomer (Photac Fill) showed significant increase in microhardness after application of different whitening toothpastes compared to resin composite (Filtek Z250 XT) and resin modified glass ionomer (Fuji ll LC). In our study, comparison between pre- and post-treatment for all whitening toothpastes, there was statistically significant difference in post-treatment of Optic White and Intense White toothpastes compared to control and 3D White. This suggests that the ingredients in these two whitening toothpastes have the potential to alter the surface properties of restorative materials especially microhardness.

One of the limitations of this study was the use of one resin composite, one resin reinforced glass ionomer, and one resin-modified glass ionomer as well as three whitening toothpastes only. It would be beneficial if more and different restorative materials as well as more whitening toothpastes are tested. Furthermore, application of whitening toothpastes after shorter application time on the immediate and aged specimens was not tested in this study. In addition, the surface of specimens was flat which do not mimic clinical situation. However, despite these limitations, the research does describe a number of positive links between *in vitro* efficacy and clinical efficacy. Future researches are recommended to compare the effect of various whitening toothpastes on other properties of different restorative materials and hard tissues of the teeth.

CONCLUSIONS

Under the experimental conditions and within the limitations of this *in vitro* study, the following conclusions can be drawn: Microhardness increased after application of the whitening toothpastes and toothbrushing simulation for all combination of tested restorative materials and whitening toothpastes. The microhardness of FIiltek Z250XT with 3D White post-application of the whitening toothpastes and brushing was lowest compared to other toothpastes and control.

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