ORIGINAL ARTICLE

Effect of whitening toothpastes on bonding of restorative materials to enamel of primary teeth

FY Abdelmegid

Department of Oral Medicine and Diagnostic Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

Abstract

Objective: The aim of this *in vitro* investigation was to measure shear bond strength (SBS) of a resin composite and a resin-modified glass ionomer to enamel of primary teeth after application of different whitening toothpastes (WTs).

Materials and Methods: Eighty labial enamel surfaces of primary incisors were randomly distributed into 8 groups of 10 each according to the surface treatment and bonding material. G1 and G2, control (brushed with water without WT); G3 and G4, (brushed with Colgate Optic White WT [Colgate-Palmolive Company, New York, NY, USA]), G5 and G6, (brushed with Crest Pro-Health Whitening WT [Procter and Gamble, Cincinnati, OH, USA]) and G7 and G8, (brushed with Arm and Hammer Advance White Extreme Whitening with Stain Defense WT [Church and Dwight Co., Princeton, NJ, USA]). SBS was measured at a crosshead speed of 0.5 mm/min and the type of bond failure was assessed using a stereomicroscope.

Results: There was significant difference between SBS of composite resin in groups 1, 3, 5, and 7 ($P < 0.001$), but no difference between resin-modified glass ionomer in groups 2, 4, 6, and 8 ($P < 0.056$). SBS of group 1 (control) was greater than groups 3, 5, and 7. There was a significant difference between group 1 and group 2 as well as group 7 and group 8 ($P < 0.001$).

Conclusions: WTs affect SBS of resin composite, but not resin-modified glass ionomer to enamel of primary teeth. No difference of failure modes between different groups of tested materials.

Key words: Dental enamel, restorative materials, shear bond strength, whitening toothpaste

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Introduction

Currently, numerous children are demanding bleaching of their teeth and were displeased with their color.[1,2] Therefore, the desire for whiter teeth is growing as well as increase use of tooth whitening products with wide varieties on the market.[1] The action of most of the available whitening preparations, either by teeth bleaching or by the elimination of external stain.[3] The latter products contain particular chemical and/or abrasives ingredients to improve removal and/or prevention of stain and are called whitening toothpastes (WTs).[3] WTs represent more than 50% of the over-the-counter (OTC) products and are intended to enhance appearance of teeth by eliminating stains from the surface by chemical chelation, mild polishing or other nonbleaching actions as indicated by the American Dental Association Seal of Acceptance program.[4,5]

Whitening toothpastes may comprise other components that enhance the cleaning of the abrasive by assisting the elimination and/or prevention of stains from the external surface.[3] These components include citrate, peroxide, pyrophosphate and hexametaphosphate, enzymes, or optical agents like blue covarine.[3] A review identified the industrial science behind WTs and their effectiveness was published on 2010 and summarized studies 57, of which 22 were *in vitro* and 35 were clinical.[3] Randomized clinical trials showed

Address for correspondence:
Dr. FY Abdelmegid,
Department of Oral Medicine and Diagnostic Sciences,
College of Dentistry, King Saud University, P. O. Box 60169,
Riyadh 11545, Saudi Arabia.
E-mail: fabdelmegid@ksu.edu.sa

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no lightening action of WTs, except for one brand and that treatment with sodium hexametaphosphate-containing toothpastes are capable of eliminating stain from the external surface of the teeth comparable to toothpastes with more abrasives.[6,7] Studies evaluated the influence of whitening and conventional toothpastes on surface roughness of dental ceramics and titanium and titanium alloys reported that brushing with a WT increased roughness of their surfaces.[8,9] A study assessed the shear bond strength (SBS) of resin composite to human enamel and dentin after using a WT comprising carbamide peroxide reported increased bond strength of restorative systems.[10] Another study evaluated bond strength of resin composite to enamel after application of WTs reported significant reduction between the control and WTs and adhesive failures were predominant.[11]

The American Academy on Pediatric Dentistry recommended further research of dental whitening agents in children.[1] Furthermore, several studies revealed that certain WTs comprising carbamide or hydrogen peroxide may produce lesions on the surface of enamel.[10-13] It is not completely known whether WTs may affect the strength of bonding of the restorative material to enamel of primary teeth. Therefore, the aim of this *in vitro* investigation was to measure SBS of a resin composite and a resin-modified glass ionomer to enamel of primary teeth after application of different WTs. The null hypothesis in the present study was that the application of WTs does not influence the SBS of the resin composite and resin-modified glass ionomer to enamel of primary teeth.

Materials and Methods

The research procedures were approved by the Ethical Committee of Human Studies at College of Dentistry Research Center. Eighty extracted maxillary primary incisors with intact labial surfaces were used in this study. All the teeth were obtained from different clinics, cleaned, and stored in 1% thymol solution. Roots were removed using low-speed carborundum disks (3M™ ESPE™, St. Paul, MN, USA) under water spray. Specimens were mounted inside a cylindrical-shaped plastic, 2.5 cm in diameter and with a height of 2.5 cm using autopolymerizing acrylic resin (Ortho-Jet, Lang Dental MFG. Co., Inc., IL, USA). The labial surfaces were slightly polished with 320-grit and 600 grit silicon carbide abrasive papers (Automata Grinding and Polishing Unit, Jeanwirtz Gmbh and Co., Charlottestrabe Dusseldorf W, Germany) with water lubrication to create a flat enamel surfaces without exposing dentin. Specimens were stored in distilled water at room temperature (27°C) after polishing and before use. Then, the specimens were randomly divided into 8 groups of 10 each as follows: G1 and G2, control (brushed with water without toothpaste); G3 and G4, (brushed with WT-1), G5 and G6, (brushed with WT-2); and G7 and G8, (brushed with WT-3). A modification of the techniques described by Jin *et al*.,[14] was used. Manual brushing with a new toothbrush (Oral-B Mickey for Kids, Soft Indicator Bristles, Procter and Gamble, Weybridge, UK) for 4 min in a circular motion to simulate clinical use by the same investigator and with the assigned WT or water (control) directly applied to the labial enamel surfaces according to assigned group. Afterward, the pastes or water were left for 10 min to allow undisturbed interactions of these materials with the enamel surface. The specimens were cleaned in an ultrasonic bath (Sonicer, Yoshida Dental Mfg. Co. Ltd. Osaka, Japan) and placed in distilled water at room temperature for 24 h. This procedure was repeated over 12 days. The total application time of WT or water was 168 min which is equal to the application of 2 min, twice a day, WT for 6 weeks which is the maximum time needed to make teeth appear whiter.[3,15-17] WTs used in this study are listed in Table 1. The specimens were cleaned again in an ultrasonic bath and placed in distilled water at room temperature for 24 h before bonding procedures. The restorative dental materials used in this study included a nanohybrid composite (Tetric N-Ceram; Ivoclar Vivadent Inc., NY, USA) and a resin-modified glass ionomer (Photac Fil; 3M ESPE, 3M ESPE, Seefeld, Germany). All materials were applied according to the manufacturer's instructions and light-cured with a light-emitting diode (LED) (Elipar™ S10 LED Curing Light-3M ESPE). After application of the adhesive, a standard polyvinyl chloride tube with internal diameter of 2 mm and a height of 2 mm was placed perpendicularly on the enamel surface and the resin composite and the resin-modified glass ionomer were carefully inserted into the tube and cured. The specimens were placed in distilled water for 24 h at room temperature prior to SBS testing.

The SBS was measured for each specimen in a universal testing machine (Instron, model no. 8500, Illinois Tool Works Inc., Norwood, MA, USA) at 0.5 mm/min crosshead speed. Bond strength was expressed in MPa. Evaluation of mode of failure and fractured surfaces were examined by two investigators using a stereomicroscope (Nikon Model C-DSD230, Nikon Co. Tokyo, Japan) with digital camera (DXM1200F Nikon Co. Tokyo, Japan) at × 25. Failures were classified as: Adhesive interface failure (100% of the bonded interface failed between enamel and bonding resin); cohesive failure (100% of failure in resin composite and/or enamel); or mixed failure (partial cohesive failure and partial adhesive failure).

Statistical analysis

Collected data were analyzed using software package statistical analysis (SPSS) statistical software version 18 (SPSS Inc., Chicago, IL, USA). Descriptive statistics was used to describe the quantitative and categorical outcome variables. A one-way analysis of variance (ANOVA) was used to compare SBS

Table 1: Relevant ingredients of the tested whitening toothpastes

Toothpastes	Relevant ingredients	Manufacturer
Colgate Optic White	Sodium monofluorophosphate - calcium pyrophosphate, silica, tetrasodium pyrophosphate, hydrogen peroxide, phosphoric acid	Colgate-Palmolive Company, New York, NY, USA
Crest Pro-Health Whitening	Stannous fluoride - hydrated silica, sodium hexametaphosphate, trisodium phosphate	Procter and Gamble, Cincinnati, OH, USA
Arm & Hammer Advance White Extreme Whitening with Stain Defense	Sodium fluoride - sodium bicarbonate, tetrasodium pyrophosphate, peroxide, baking soda	Church and Dwight Co., Princeton, NJ, USA

Table 2: Means and SD of SBS in MPa for different groups (n=10)

Material	WT	Group	Mean	SD
Tetric N-Ceram (composite resin)	Control - none	1	25.41	1.18
	Colgate Optic White	3	16.69	1.41
	Crest Pro-Health Whitening	5	15.51	1.86
	Arm and Hammer Advance White Extreme Whitening with Stain Defense	7	23.15	1.96
Photac Fil (resin-modified glass ionomer)	Control - none	2	16.08	1.46
	Colgate Optic White	4	16.43	1.06
	Crest Pro-Health Whitening	6	14.94	1.25
	Arm and Hammer Advance White Extreme Whitening with Stain Defense	8	15.36	1.32

SD=Standard deviation; WT=Whitening toothpastes; SBS=Shear bond strength

across different groups followed by Tukey honestly significant difference (HSD) test for multiple comparisons. A ($P < 0.05$) was considered as statistically significant.

Cohen's kappa statistics was calculated to quantify an agreement between the two examiners in assessing the three types of failures (adhesive, cohesive, and mixed) in each group. The Kappa value for inter-examiner reliability in assessing the three types of failures was 0.83 which indicates very good agreement between the two examiners.

Results

Table 2 shows means and standard deviations of SBS values (MPa) for all groups. For composite resin, one-way ANOVA showed significant difference of the SBS between groups 1, 3, 5, and 7 ($P < 0.001$). Group 1 (control) was higher than groups 3, 5, and 7. Tukey's HSD test showed that SBS of groups 3 and 5 were significantly different than group 1 ($P < 0.001$). There was a significant difference of the SBS between group 1 and group 7 ($P < 0.019$). There was no significant difference between group 3 and group 5 ($P < 0.383$). In contrast, for the resin-modified glass ionomer, there was no significant difference between all groups 2, 4, 6, and 8 ($P < 0.056$). There was a significant difference between group 1 and group 2 as well as group 7 and group 8 ($P < 0.001$). However, there was no significant difference between group 3 and group 4 ($P < 0.648$) as well as group 5 and group 6 ($P < 0.435$). Stereomicroscopic assessment of the fractured surfaces and types of bond failure for each group is summarized in Table 3. For bond failure, there was no statistically significant difference in the association between different groups and the three types of failure. Table 4 shows combined types of bond failure and corresponding mean/std. deviation for all groups.

Table 3: Types of bond failure for each group - frequency (%)

Group	Failure			Total
	Adhesive failure	Cohesive failure	Mixed failure	
1	1 (10)	3 (30)	6 (60)	10
2	3 (30)	3 (30)	4 (40)	10
3	4 (40)	2 (20)	4 (40)	10
4	5 (50)	3 (30)	2 (20)	10
5	3 (30)	0 (0)	7 (70)	10
6	3 (30)	4 (40)	3 (30)	10
7	2 (20)	4 (40)	4 (40)	10
8	7 (70)	2 (20)	1 (10)	10
Total	28 (35)	21 (26.25)	31 (38.75)	80

Table 4: Combined types of bond failure and corresponding mean/SD for all groups

Failure	n	Mean	SD
Adhesive failure	28	16.64	3.19
Cohesive failure	21	18.26	4.023
Mixed failure	31	18.95	4.46

SD=Standard deviation

Discussion

Attentiveness by children, patients, and customers in tooth whitening has increased in recent years.[1] OTC products for at-home use include WTs have increased because of

the patient convenience and lower associated costs.[1] Furthermore, the results of *in vitro* studies are controversial, little evidence and information known about the bonding of resin composite and resin-modified glass ionomer to enamel of primary teeth. The null hypothesis was rejected for the resin composite and accepted for resin-modified glass ionomer as the tested WTs affected bonding of tested restorative materials to enamel of primary teeth. Clinical procedures for assessing the effectiveness of WTs usually evaluate either removal of stain or prevention, where variations in the degree of stain are measured classically over 2–6 weeks.[3] Therefore, in the present study, the total application time of WT or water was 168 min which is equal to application of 2 min, twice a day, WT for 6 weeks which is the maximum time needed to make teeth appear whiter.[3,15-17] However, WT that contains blue covarine can have an immediate effect.[3,15-17]

In the present study, SBS of resin composite showed a significant difference between groups 1, 3, 5, and 7. Group 1 (control) was higher than groups 3, 5, and 7 and SBS of groups 3 and 5 were significantly different than group 1. Group 2 exhibited the lowest SBS value (15.51) compared to other groups. These results were in agreement of another study, which reported significant reduction between the control and WTs.[11] In contrast, a study assessed the SBS of resin composite to human enamel after using a WT comprising carbamide peroxide reported increased bond strength of restorative systems.[10] Changes in bond strength values may be related to the surface roughness and hardness of the enamel as the application of the WT to enamel increased the enamel surface roughness and decreased hardness values.[18] It was reported that bleaching agents decreased bond strength due to changes in the enamel in the form of increase in surface porosity.[19,20] Moreover, some investigators reported the critical elements causing reduction of bond strength to enamel such as a decrease in microhardness and loss of calcium.[21,22] In the present study in contrast to the effect of WTs on resin composite, the resin-modified glass ionomer showed no significant difference between all groups 2, 4, 6, and 8. There was a significant difference between control groups 1 and 2 as well as group 7 and group 8 where arm and hammer was used. However, there was no significant difference in SBS between group 3 and group 4 where Colgate Optic White (Colgate-Palmolive Company, New York, NY, USA) was used as well as group 5 and group 6 where Crest Pro-Health Whitening (Procter and Gamble, Cincinnati, OH, USA) was used. In addition, in the present study, there was a significant difference between group 1 (control) and group 7 (Arm and Hammer). There was no significant difference between group 3 (Colgate Optic White) and group 5 (Crest Pro-Health Whitening). Difference in SBS between different groups may be due to composition of the WTs and restorative materials used. In the present study, stereomicroscopic assessment of the fractured surfaces and types of bond failure for each group showed no significant difference in the association between different groups and the three types of failure. In contrast, another study reported that adhesive failures were predominant.[11] This difference could be due to the difference in methodology. Though cohesive failures occurred in primary enamel probably due to hydrogen peroxide effect.[23,24] There was no difference of failure modes between different groups of the resin composite and resin-modified glass ionomer. The residual oxygen in the enamel subsequent to application of bleaching agents can inhibit the proper polymerization of the adhesive and so add to the reduction of values of bond strength.[23,24] In addition, it has been proposed that changes occur in the mineral and protein components of the enamel surface layer which could be accountable for the decrease in bond strength.[25,26]

In the present study, thermocycling of the specimens was not used as previous study demonstrated that thermocycling using 1800 cycles did not influence the SBS of the tested materials to enamel and dentin.[27] It may be beneficial to test bond strength after thermocycling in future studies. In the present study, abrasive particles and other component of WTs may not be in direct contact of the enamel surface as throughout the process of tooth brushing, the particles of the abrasive can be confined between the surface of the tooth and the toothbrush bristle.[28] In addition, several crucial factors have been confirmed to affect the abrasive action such as particle size, shape, hardness, concentration, and load applied.[29] In the present study, applied load was performed by the same investigator, however, this was difficult to control in standard way as this was done manually. A study investigated the pH of 21 products of tooth-whitening available in the market showed a wide range of their pH from 3.76 (highly acidic) to 9.68 (highly alkaline).[30] However, the lowest pH levels have been reported for the OTC whitening products and in general low pH can be expected to damage enamel more.[30] In the present study, the pH of the WTs was not measured, but it could have low pH as reported in the previous study by Majeed *et al*.[30]

A randomized controlled clinical trial determined the effectiveness of a sodium bicarbonate WT reported effectiveness for removing extrinsic tooth stain and whitening teeth.[31] A WT delivering 0.243% sodium fluoride, 1.0% hydrogen peroxide and sodium tripolyphosphate in silica base provided superior tooth whitening and prevention of external tooth stain than the control toothpaste.[32] Some of these toothpastes have hydrogen peroxide in their composition, whereas others remove extrinsic stains by abrasive action.[6] The most common used abrasives are calcium carbonate, hydrated silica, aluminum oxide, dehydrated calcium phosphate, sodium bicarbonate, alumina, and perlite.[4,33] Abrasives not only efficiently eliminate external stains on

the tooth surface but also assist in preventing stains from reforming on the tooth surface by brushing and removing immature stains.[1,2] WTs have been intended to maximize cleaning while minimizing wear of the hard tissue. Abrasive formulations in the form of "soft silica" has a substantial better cleaning over 6 weeks compared to conventional silica.[1,2,34] In the present study, silica was part of Colgate Optic White and hydrated silica as part of Crest Pro-Health Whitening. Combining abrasives have been reported to be effective in both elimination and prevention of stain.[34] WT with enzymatic action and abrasive action are similarly efficient in elimination of external stains on the tooth surface; however WT with abrasive action should be used with caution particularly with primary teeth due to thinner enamel and dentin and relatively larger pulps than permanent teeth.[35] As the present study showed that WTs affect SBS of resin composite but not resin-modified glass ionomer to enamel of primary teeth, dentist should be aware of this effect during bonding procedures. Furthermore, dentist should educate patients that some WTs may reduce the bond strength of resin composite to the enamel of primary teeth. However, in some cases the bond strength may still be clinically acceptable.

One of the limitations of this study was the use of one resin composite and one resin-modified glass ionomer adhesive system only. It would be beneficial if more and different restorative materials and etch-and-rinse as well as self-etch adhesive systems is tested. Furthermore, application of WTs on the bond strengths of primary teeth after shorter application time on the immediate and aged specimens was not tested in this study. In addition, actual toothbrushing with the WTs was performed for 4 min every day and WTs was left for 10 min without brushing which may affected the results. Furthermore, enamel surface was flat and no water or saliva was added to dilute toothpaste during brushing 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.

Conclusions

Under the experimental conditions and within the limitations of this *in vitro* study, the following conclusions can be drawn:

- Whitening toothpastes affect SBS of resin composite but not resin-modified glass ionomer to enamel of primary teeth
- No difference of failure modes between different groups of resin composite and resin-modified glass ionomer.

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