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Research Article

Effect of whitening toothpastes on color stability of different restorative materials

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ABSTRACT: Objective: The purpose of this study was to evaluate the effects of application of three over the counter whitening toothpastes (Colgate Optic White, Aquafresh Ultimate White and Crest 3D White) on the color stability of different esthetic restorative materials (Resin composite/Filtek Z250 XT, resin modified glass ionomer/GC Fuji II LC, and glass ionomer/Ketac Molar Quick Aplicapweek) commonly used in children.

Methods: Cylindrical specimens were prepared from each restorative material using Mylar strip with no further trimming, finishing or polishing or after finishing and polishing. The specimens were randomly assigned into 4 main groups according to each restorative material. All specimens were measured for color (Baseline - T1). All specimens were finished and polished using Sof-Lex finishing and polishing system according to the instructions of the manufacture. Then, all specimens according to the groups were brushed with water without whitening toothpastes (control) or brushed with the different whitening toothpastes. The specimens were rinsed before color measurement (Testing Phase Three – T2). Statistical analysis were performed using paired t-test used and Tukey's HSD (Honestly Significant Differences) Post Hoc Test.

Results: Delta E (DE) showed significant difference (*P*=0.0001) between baseline (T1) and after application of whitening toothpastes (T2) for all three restorative materials. DE showed significant difference (*P*=0.0001) between baseline (T1) and after application of whitening toothpastes (T2) for distilled water, Colgate Optic White, and Aquafresh Ultimate White. There was significant difference (*P*=0.001) between baseline (T1) and after application of whitening toothpastes (T2) for Crest 3D White.

Conclusion: The use of Colgate Optic White, Aquafresh Ultimate White and Crest 3D White whitening toothpaste for two minutes twice each day for 15 days does cause significant change in the color of the Filtek Z250 XT, GC Fuji II LC, and Ketac Molar Quick Aplicap restorative materials. The highest color change was recorded for Ketac Molar Quick Aplicap and use of Colgate Optic White. Color change is dependent upon the type of restorative material and whitening.

Key Words: Bleaching Toothpaste, Color, Restorative Materials, Spectrophotometer.

Introduction

The action of the over-the-counter at-home bleaching products such as toothpastes, strips, and mouthwashes is built ordinarily on two mechanisms: the removal and control of extrinsic stains through the action of abrasive agents and bleaching of intrinsic stains using oxidizing agents to break down the organic molecules present in the tooth structure (Heymann 2005; Joiner 2006, Bortolatto et al. 2016). Over-the-counter bleaching products usually have low levels of hydrogen peroxide (3% - 6%) and are self-applied to teeth once or twice per day for up to 14 days, depending on the dose and time of exposure (Joiner 2006). Bleaching toothpastes work by removing and/or controlling extrinsic staining by the action of optimized abrasives, surfactants, enzymes and polyphosphates (Joiner 2010). These may be used in the maintenance and retouching techniques after at-home or in-office bleaching or with bleaching function and, in this case, they must be used regularly such as twice a day, and take 2-4 weeks for effects to begin to show (Joiner 2004; Joiner 2010).

Esthetic restorative materials are widely used in dentistry as an anterior restorative and also for minimal invasive techniques.

Color, surface roughness and microhardness are the three important factors for any restorative material for its longevity (Roopa et al. 2016). Surface hardness is an important aspect for the restorative material. With low surface hardness it is susceptible for scratches and provoke failure of restorations (Claydon et al. 2004). Surface structure which is rough can lead to staining of material and discoloration, which may compromise the quality restoration. Thus it is very important to know the effect of a dentifrice abrasion on loss of restorative materials (Meyers et al. 2000). Acceptable performance of esthetic restorative materials is dependent on their resistance to degradation in the oral environment (Asmussen & Hansen 1986). Among the contributing factors are abrasion resulting from mastication, attrition, corrosion, erosion, and effects of hygiene procedures (Asmussen & Hansen 1986; Schmitt et al. 2011; da Rosa et al. 2016). Tooth brushing is an oral hygiene method that can increase the surface roughness of resin composites (Kamonkhantikul et al.

2014). Similarly, to dental hard tissues, when direct restorative materials such as resin composites are exposed to the tooth brushing abrasion process, an increase in surface roughness and loss of gloss occur (da Costa et al. 2010; Jin et al. 2014; Lefever et al. 2014). As a result, an accumulation of biofilm in this area is facilitated, leading the development of gingivitis and discoloration of the body restoration (Heintze et al. 2010; Schmitt et al. 2011). This negative effect is usually associated with the organic matrix of the resin composite (Ertas et al. 2006; Rüttermann et al. 2008). Moreover, porous resin can promote biofilm accumulation and superficial degradation (Asmussen & Hansen 1986). Esthetically negative color changes in the resin composite can befall by penetration of coloring agents on the surface of the material and also from the physicochemical formulation of the material when exposed to the oral environment (Schmitt et al. 2011; Lepri & PalmaDibb 2014).

The International Commission on Illumination (CIE) defined a tridimensional color space which provides a representation for color perception (Joiner 2004). The three axis are L*, a* and b*, where L* represents a measure of the object's luminosity and the axis a* and b* represent chromaticity coordinates (Joiner 2004). Some tooth bleaching studies using peroxide based products have shown that the yellow-blue axis is the most important for bleaching color perception than a change in the axis L* and a* (Gerlach et al. 2000; Gerlach et al. 2002). Furthermore, a reduction of the b* value occurs more quickly and to a higher degree than changes to the L* values (Kleber et al. 1997; Goodson et al. 2004).

Whitening toothpastes can have some deleterious effect on restorative materials since they are known to have high abrasives. Thus this study was undertaken to know the effect of whitening dentifrice on esthetic restorative materials. The American Academy on Pediatric Dentistry recommended further research of dental whitening agents (AAPD 2015). Therefore, the aim of this *in vitro* investigation was to evaluate the effects of application of three over the counter whitening toothpastes (Colgate Optic White, Aquafresh Ultimate White and Crest 3D White) on the color stability of three esthetic restorative materials (Resin composite, conventional glass ionomer and resin modified glass ionomer) commonly used in children. The null hypothesis in the present study was that the application of whitening toothpastes does not influence the color stability of different esthetic restorative materials.

Materials and Methods

Sixty shade B2 cylindrical specimens (10 mm diameter, 2 mm thickness) were prepared from each restorative material according to manufacturer's instructions, using cylindrical molds. The molds were placed onto a glass microscopic slide and the restorative material were placed into the mold, and then Mylar strip (Mylar Uni-Strip, Caulk/Dentsply, Milford, DE, USA) and a glass microscopic slide were placed onto the restorative material surface. The glass slide was pressed until it has a tight contact with the metal mold to flatten the surface. The metal mold has a dot to mark the bottom surface of each specimen and facilitate identification of the top surface where color measurement to be performed. Every specimen was light cured if indicated (Elipar Highlight, 3M ESPE, St. Paul, MN, USA) on each side according to the manufacturer's instructions. The glass slide and Mylar strip were removed with no further trimming, finishing or polishing. All specimens were prepared at room temperature (approximately 25^{o}C). Following preparations, all specimens were stored in containers containing distilled water in an incubator/humidifier (GI2 So-Low Cincinnati, OH, USA) at 37°C for 24 hours. Then, the 60 specimens prepared from each material was randomly assigned into 4 groups with 15 specimens per group. The restorative materials, different whitening toothpastes and groups that were used in this study are listed in Table 1.

Table 1. Distribution of different groups, restorative materials and whitening toothpastes

Group Number	Restorative System/Material	Different Whitening Toothpastes/Distilled Water	Number of Specimens
1	Resin Composite/Filtek Z250 XT	Distilled Water	15
2		Colgate Optic White	15
3		Aquafresh Ultimate White	15
4		Crest 3D White	15
5	Resin Modified Glass ionomer/GC Fuji II LC	Distilled Water	15
6		Colgate Optic White	15
7		Aquafresh Ultimate White	15
8		Crest 3D White	15
9	Conventional Glass ionomer/Ketac Molar Quick Aplicap	Distilled Water	15
10		Colgate Optic White	15
11		Aquafresh Ultimate White	15
12		Crest 3D White	15

All specimens were measured for color (Testing Phase One – T1). The color was measured 3 time in the center of each specimen using a spectrophotometer (Color-Eye 7000, GretagMacbeth LLC, New Windsor, NY, USA) against a white background using LABCH color space relative to CIE (Commission Internationale de l'Eclairage) standard illuminants D65, CWF and C to measure ΔE (color difference) for SCI (Specular Component Included).

All specimens were then finished and polished using The Sof-Lex finishing and polishing system according to the instructions of the manufacture. All specimens were stored for 24 hours in an incubator/humidifier at 37°C. Then, all specimens according to the groups in Table 1 brushed with water without whitening toothpastes (control) or brushed with the different whitening toothpastes for one hour which is equivalent to brushing for two minutes twice each day for 15 days. Each specimen was brushed using electrical toothbrush with power of 1.7W and frequency 50, 60 Hz (Oral B, Braun GmbH, frankfurter Kronberg\Ts. Germany). To standardize the force of brushing, the electric toothbrush was placed in a created mold to stabilize/hold the brush in the same position during brushing and water (5 drops) or different anti-erosion toothpastes (250 mg) were added to each specimen every 10 minutes. 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. The specimens were rinsed using distilled water for five minutes and blotted dry with tissue paper before color measurement which was repeated similar to baseline measurement (Testing Phase Two – T2).

The change in color of the specimens was measured by the color difference formula ΔE* which is the difference between final and initial values. The color change value ΔE*ab was calculated according to the following formula: $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]1/2$ where L* stands for lightness, a* for green-red (-a=green; +a=red) and b* for blue-yellow (-b=blue; +b=yellow). Before each measurement session, the colorimeter was calibrated according to the manufacturer's recommendations by using the supplied white calibration standard.

Statistical analysis was performed using paired t-test and Tukey's HSD (Honestly Significant Differences) Post Hoc Test. The color values between different groups, within each group, and experimental conditions was analyzed. In addition, descriptive statistics of all parameters were tabulated using SPSS Version 16.0 (SPSS Inc., Chicago, Ill). All statistical analyses were set at a significance level of $p<0.05$.

Results

The mean and Std. deviation of the color of Filtek Z250 XT, GC Fuji II LC, and Ketac Molar Quick Aplicap at baseline (T1) and after application of whitening toothpastes (T2) is shown is Table 2.

Table 2. Mean and Std. deviation and comparing time T1 and T2 within each restorative material

Restorative Material	**Time**	**N**	**Mean**	**Std. Deviation**	***P*-value**
Filtek Z250 XT	T1	180	1.73	0.85	0.0001*
	T2	180	2.23	1.06	
GC Fuji II LC	T1	180	1.97	1.28	0.0001*
	T2	180	3.09	1.36	
Ketac Molar Quick Aplicap	T1	180	3.15	1.84	0.0001*
	T2	180	4.05	2.39	

* Significant

DE showed significant difference (*P*=0.0001) between baseline (T1) and after application of whitening toothpastes (T2) for all three restorative materials.

The mean and Std. deviation of the color of the three whitening toothpaste and control (distilled water) at baseline (T1) and after application of whitening toothpastes (T2) is shown is Table 3

Table 3. Mean and Std. deviation and comparing time T1 and T2 within each whitening toothpaste and control

Different Whitening Toothpastes/Distilled Water	**Time**	**N**	**Mean**	**Std. Deviation**	***P*-value**
Distilled Water	T1	135	2.19	1.46	0.0001*
	T2	135	2.83	1.27	
Colgate Optic White	T1	135	2.40	1.83	0.0001*
	T2	135	3.87	2.57	
Aquafresh Ultimate White	T1	135	2.14	1.17	0.0001*
	T2	135	2.88	1.38	
Crest 3D White	T1	135	2.40	1.53	0.001*
	T2	135	2.92	1.73	

* Significant

DE showed significant difference (*P*=0.0001) between baseline (T1) and after application of whitening toothpastes (T2) for distilled water, Colgate Optic White, and Aquafresh Ultimate White. Also, there was significant difference (*P*=0.001) between baseline (T1) and after application of whitening toothpastes (T2) for Crest 3D White.

The mean and Std. deviation of the color of the three whitening toothpaste and control (distilled water) and the three restorative materials at baseline (T1) and after application of whitening toothpastes (T2) is shown is Table 4.

Table 4. Mean and Std. deviation and comparing time T1 and T2 within each whitening toothpaste and control as well as each restorative material

Different Whitening Toothpastes/Distilled Water	Material	Time	N	Mean	Std. Deviation	*P*-value
Distilled Water	Filtek Z250 XT	T1	45	1.83	1.074	0.115
		T2	45	2.08	1.037	
	GC Fuji II LC	T1	45	1.44	0.941	0.0001*
		T2	45	3.26	0.560	
	Ketac Molar Quick Aplicap	T1	45	3.31	1.568	0.306
		T2	45	3.14	1.624	
Colgate Optic White	Filtek Z250 XT	T1	45	1.50	0.737	0.0001*
		T2	45	2.11	0.936	
	GC Fuji II LC	T1	45	1.83	1.213	0.0001*
		T2	45	2.92	1.499	
	Ketac Molar Quick Aplicap	T1	45	3.86	2.203	0.0001*
		T2	45	6.59	2.290	
Aquafresh Ultimate White	Filtek Z250 XT	T1	45	1.78	0.769	0.0001*
		T2	45	2.98	1.011	
	GC Fuji II LC	T1	45	2.22	1.270	0.115
		T2	45	2.66	1.204	
	Ketac Molar Quick Aplicap	T1	45	2.42	1.308	0.003*
		T2	45	3.01	1.795	
Crest 3D White	Filtek Z250 XT	T1	45	1.80	0.743	0.679
		T2	45	1.76	0.847	
	GC Fuji II LC	T1	45	2.40	1.461	0.001*
		T2	45	3.53	1.751	
	Ketac Molar Quick Aplicap	T1	45	3.01	1.915	0.105
		T2	45	3.48	1.816	

* Significant

For the distilled water (control), there was significant difference between T1 and T2 for GC Fuji II LC (*P*=0.0001) but not for Filtek Z250 XT (*P*=0.115) and Ketac Molar Quick Aplicap (*P*=0.306). For Colgate Optic White, there was significant difference between T1 and T2 for the three restorative materials (*P*=0.0001). For Aquafresh Ultimate White, there was significant difference between T1 and T2 for Filtek Z250 XT (*P*=0.0001) and Ketac Molar Quick Aplicap (*P*=0.003) but not for GC Fuji II LC (*P*=0.115). For Crest 3D White, there was significant difference between T1 and T2 for GC Fuji II LC (*P*=0.001) but not for Filtek Z250 XT (*P*=0.679) and Ketac Molar Quick Aplicap (*P*=0.105).

Discussion

The null hypothesis in this study was rejected because there was a difference in color stability after application of whitening toothpastes on the three esthetic restorative materials tested. Color stability, which compromises the restoration longevity, continues to be a problem inherent to the material (Mundim et al. 2010; Kaizer et al. 2012). Color changes occur due to staining in the material surface and changes in opacity as a result of adhesive failures at the matrix/filler interface (Catelan et al. 2010), water and dye absorption by the material (Gregorius et al. 2012), surface roughness (Gönülol & Yilmaz 2012), diet and oral hygiene (Nasim et al. 2012). On the other hand, staining may be influenced by the chemical structure and size/type of composite filler particles (Erdemir et al. 2012). The hydrophilic resin matrix can interfere with the volume of water sorption by the polymer network (Ferracane 2006) resulting in discoloration with a whiter and opaque tonality (Pires-de-Souza Fde et al. 2007). When the resin matrix is hydrophobic, there will be less water sorption and little change in color tone will be observed ((Inokoshi et al. 1996). Unreacted monomers also act as resin matrix plasticizers by changing the material physical properties, especially hardness and surface roughness (Ferracane 2006). The monomer TEGDMA present in some resin composites has greater predisposition to water sorption, increasing aqueous solubility of the polymer formed (Vichi et al. 2004), decreasing color stability due to increase in polymer free volume, consequently enabling more space for water molecules to diffuse into the polymeric structure (Gönülol & Yilmaz 2012; Erdemir et al. 2012). The latter phenomenon, called composite ‘‘plasticization’’ described by Ferracane et al. (1998), decreases the hardness of the polymeric matrix (Catelan et al. 2010) and can be used to justify the greater DE of (Roselino et al. 2013). Previous studies concluded that a low concentration of filler particles in a composite may or may not present higher DE values (Schulze et al. 2003; Lee & Powers 2007; Roselino et al. 2013). The larger the abrasive particles, the higher its degree of abrasiveness and the greater its efficacy in removing stains from stained structures (Camargo et al. 2001). There was no composite color change when specimens submitted to brushing with different dentifrices.

Resin composite materials have been used for many years and manufacturers are trying to improve the handling property, strength and polish ability to make a universal material for restoration (Meyers et al. 2000). Color and transparency are the important components of restorative materials used for appearance. Clinically it is important that the uncured restorative materials matched should retain the translucency as well as color after curing and also after it reaches its equilibrium in environment (Gross et al. 2001). Teixeira et al. (2005) fabricated 60 specimens from each restorative material in a standardized mold to ensure standardized shape and size and respective materials were sandwiched between Mylar strips and two glass plates. The specimens of each material in the present study were prepared in a similar way. Also, in this study for the brushing purpose to standardize the brushing technique a powered toothbrush with standardized pressure was used. Also, 250 mg of the whitening toothpaste was used similar to a previous study (Momoi et al. 1997). Also, the second readings (T2) were taken after brushing for what is equal to 15 days since the recommendation of whitening toothpaste for usage by the manufacturers was two weeks to achieve the whiteness of teeth. In this study we stored the specimens in distilled water while other studies used artificial or human saliva (Ashcroft et al. 2008; Joiner et al. 2008b).

Importance has been given to dental aesthetics these years thus tooth whitening is an important aspect of dentifrices. Many dentifrices with different formulations have been introduced in market mainly targeting to improve efficiency of cleaning and whitening of teeth. Tooth whitening can be done with bleaching agents like hydrogen peroxide, carbamide peroxides and the abrasives present in dentifrices (Teixeira et al. 2005). One of the major disadvantages of resin based material is its wear resistance. This varies in different patients and different areas in same patient. Anterior teeth are usually affected more due toothbrush/dentifrice wear compared to all other areas of the mouth (Korkmaz et al. 2008). Esthetic quality of restoration depends on surface texture, if it is rough leads to decreased gloss and discoloration. Rougher surface also give rise to staining, accumulation of plaque which may lead to secondary caries (Meyers et al. 2000). A study evaluated the effects of mechanical brushing on the stability of color and surface roughness of two composites concluded that abrasiveness of dentifrice does not change the color (Roselino et al. 2013).

Testing for color stability was done using a spectrophotometer. The parameter DE (total color change) for each specimen was recorded as displayed on the computer. A similarity between our current study and other studies is the use of a spectrophotometer for color measurement (Torres et al. 2013; Dantas et al. 2015). In contrast, other studies evaluated the color alteration by digital images or a colorimeter (Ashcroft et al. 2008; Collins et al. 2008, Joiner et al. 2008a; Joiner et al. 2008b). The results showed a highly significant color change with whitening dentifrice at T2 most of the tested material after application of the whitening toothpastes. The probable reason for the highly significant change in color could be due to the ingredients of whitening toothpaste. Whitening dentifrice had an extra ingredient called perlite. Perlite is an amorphous mixed glossy silicate of volcanic origin, which is chemically inert and neutral in pH. Perlite is well known for its use in professional prophylactic pastes where it has been shown to exhibit excellent cleaning and polishing properties. In addition, the combination of silica and perlite in toothpaste has been demonstrated to have significant stain removal and prevention benefit in a clinical study (Momoi et al. 1997). Thus the presence of perlite acting as an abrasive in whitening dentifrice could be the reason for significant change in color of restorative material. Exposure of the inner surface due to the wear of the material could be attributed to the color change. DE more than 3.3 was considered a clinically unacceptable level of alteration, detectable by the human eye, thus for esthetic reasons, suggesting replacement of the restorative material (Inokoshi et al. 1996; Schulze et al. 2003).

The results of this investigation should consider the limitations of the study, including its *in vitro* setting, which may not simulate cumulative long-term effect of whitening toothpastes *in vivo*. This may be different if we used the tested the whitening toothpastes for longer number of hours and repeated the use every day. In addition, the clinical condition in the mouth is not easy to mimic in the laboratory (Eliades et al. 2005). However, in this *in vitro* study, standardization of experimental conditions was advantage and the results demonstrated a clear correlation between color change of the tested restorative materials and the whitening toothpastes.

Conclusions

Within the limitations of this *in vitro* study, it can be concluded that the use of Colgate Optic White, Aquafresh Ultimate White and Crest 3D White whitening toothpaste for two minutes twice each day for 15 days does cause significant change in the color of the Filtek Z250 XT, GC Fuji II LC, and Ketac Molar Quick Aplicap restorative materials. The highest color change was recorded for Ketac Molar Quick Aplicap and use of Colgate Optic White. Color change is dependent upon the type of restorative material and whitening.

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