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Research Article

Effect of Anti-Erosion Toothpastes on Surface Roughness of Different Restorative Materials

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Abstract

Purpose: The aim of this study was to evaluate the effects of three anti-erosion toothpastes (Sensodyne Proenamel, Biorepair, and Regenerate) on Surface Roughness (Sa) of three tooth-colored restorative materials: Resin Composite (RC), Glass Ionomer Cement (GI), and Resin-Modified Glass-Ionomer Cement (RMGI).

Methods: Sixty cylindrical specimens were prepared from each material and then were finished and polished and the First Surface Roughness (Sa) readings (T1) were recorded. Each material was randomly divided into 4 groups according to the anti-erosion toothpastes or water as control. Then application of the anti-erosion toothpastes or water for one hour for each group. Brushing was performed manually using electric toothbrush for one hour which is equivalent to brushing for two minutes twice each day for 15 days and then surface roughness (T2)of each specimen was recorded usinga 3D noncontact profilometer.

Result: Comparing the effect of anti-erosion toothpastes on the three restorative materials using ANOVA showed a statistically significant in the Filtek Z250 XT groups (p=0.006) but not in GC Fuji II LC groups (p=0.444) nor Ketac Fil Plus Aplicap groups (p=0.166). The highest Sa (Mean+SD) at T1 was observed in Ketac Fil Plus Aplicap (0.73+0.45) followed by GC Fuji II LC (0.32+0.09) then Filtek Z250 XT (0.16+0.02).For Filtek Z250 XT, there was statistically significant difference in surface roughness between distilled water and Sensodyne Pronamel (p=0.005) and between Sensodyne Pronamel and Regenerate (p=0.036). There was no statistically significant difference in surface roughness between different surface treatments for GC Fuji II LC(p=0.942) and Ketac Fil Plus Aplicap(p=0.447).

Conclusion: Brushing tested restorative materials with anti-erosion toothpastes resulted in significant changes on their surface roughness and the most toothpaste caused change on Filtek Z250 XT was Sensodyne Pronamel, for the GC Fuji II LC was Biorepair, and for and Ketac Fil Plus Aplicap was Regenerate. Surface roughness varied depending on the anti-erosion toothpastes and the restorative material used.

Keywords: Resin-Based Composite, Surface Roughness, Anti-Erosion Toothpastes

Introduction

Dental erosion impermanent loss of the hard dental structures chemically without the association of the microorganisms [1]. This mineral loss results in dematerialized surface and reduced micro hardness [2]. The process may be associated with an intrinsic factor, i.e. gastric acid; or it may be caused by extrinsic factors related to dietary habits and lifestyle [1]. Anti-erosion toothpastes are available in the market such as Sensodyne Pronamel [3]. Sensodyne Pronamel is a derivative of Sensodyne toothpaste with greater levels of bioavailable fluoride and potassium nitrate (5% w/w) and was suggested as effective in preventing erosion of permanent teeth [3]. The key aim of effective elements against erosion is to intensify the resistance of tooth surfaces or pellicles to acid. The effective elements may be lessened by the abrasives in the toothpastes, which is valuable in cleaning. Fluoride containing toothpastes provide part of defense but effective elements should be added in addition to, or other than, fluorides [2].

The dental restorative materials could have irregular surface characteristics that might increase plaque retention and this affects esthetic and physical properties of the dental restorative materials [4]. For this reason, clinician tends to create smooth and polish surface. Adequate finishing and polishing of dental materials give good result on esthetic aspect and reduce the plaque accumulation and extrinsic staining [5]. Many factors influence tooth roughness such as prophylaxis procedure and tooth brushing with toothpaste, which alter the quality of the surface of the restorative material [4].

The important function of dentifrices has become more specialized during the recent years, some dentifrices containing therapeutic agents that could help to reduce plaque, calculus and reduced sensitivity. Other dentifrices concern more about cosmetic effect, which contain chemical and mechanical agents to remove staining. May dentifrices formulation contain abrasive particle such as silica, calcium carbonate that have effect on surface characteristics of dental restorative materials that could cause roughness of the surface [6].

A study investigated new toothpastes with anti-erosion properties and reported that tin-containing gel reduced the erosive tissue loss 75% [7]. The use of fluoride to inhibit demineralization of enamel caused by citric acid and to promote repair was investigated and authors concluded that the value of fluoride is outweighed by the influence of sodium hexameta phosphate (NaHMP) as a mineralization inhibitor [8]. The efficacy of a new anti-erosion desensitizing toothpaste to inhibit enamel surface softening was evaluated in vitro and it was shown that treatment with fluoride-containing toothpastes helps protect sound enamel from acid-mediated surface softening and promotes re-hardening of erosive lesions [9]. A study investigated the erosion/abrasion-preventing potential of experimental amine fluoride toothpastes showed that the formulations have the potential to reduce erosion/abrasion even in the absence of dematerialized collagen [10]. A study evaluated the effect of tooth brushing using anti-erosion toothpastes on the deterioration of composite resin materials showed increase of surface roughness and found differences between the materials used [4]. However, this study recommended the need for further laboratory research and in vivo studies to understand the effects of anti-erosion toothpastes on various tooth-colored restorations.

As far as the authors are aware, little information is known regarding the effect of anti-erosion toothpastes on the surface roughness of restorative materials. Therefore, the purpose of this investigation was to assess the effects of three anti-erosion toothpastes (Sensodyne Proenamel, Biorepair, and Regenerate) on surface roughness of three tooth-colored restorative materials: Resin composite (RC)/Filtek Z250 XT, glass ionomer cement (GI)/ Ketac Fil Plus Aplicap, and resin modified glass ionomer cement (RMGIC)/GC Fuji II LC. The null hypothesis was there is no difference in the effect of the anti-erosion toothpastes tested on surface roughness of the tested tooth-colored restorative materials.

Methods and Materials

This study was approved by the Ethical Committee of Human Studies, College of Dentistry Research Center, King Saud University. The three anti-erosion toothpastes and the three restorative materials used in this study and their manufacturers are listed in Table 1. The power sample size was 0.83 and level of significant σ=0.05 with estimated standard deviation =0.8, the sample size should be at least 15 in each group. A total of 60 cylindrical specimens prepared for surface roughness evaluations from Filtek Z250 XT and GC Fuji II LC according to the instructions of the manufacturer using standard mold of 10mm diameter and 2mm thickness. These restorative materials were selected because they commonly used for restoring carious teeth in children. The materials compressed within the mold, covered by a Mylar strip (Myltrip, Dental Mylar Strips, Dent America Inc., City of Industry, CA, USA), and a microscopic glass slide (Shandon Polysine Slides, Thermo Scientific, Kalamazoo, MI, USA) were used to press the material flat even with the surface of the mold. Each specimen was light cured for 20 seconds using an LED curing light (Elipar S10, 3M ESPE, Seefeld, Germany). The bottom of the cylindrical specimen was light cured for 20 seconds. Similar specimens were fabricated using Ketac Fil Plus Aplicap according to the instructions of the manufacturer. The bottom surface of the cylindrical specimen was marked to identify it to avoid errors by measuring roughness of the bottom surface. All specimens prepared at room temperature (approximately 25oC). The specimens removed from the mold, checked to be sure that there areno evident irregularities. The specimens stored in distilled water (pH 6.8) at room temperature for 24 hours. All specimens were finished for 15 seconds at 30.000 rpm using Sof-Lex™ (3M ESPE, St. Paul, MN, USA) finishing and polishing discs according to the instructions of the manufacturer. Then polished for 15 seconds at 30.000 rpm. The specimens from each material were randomly divided into 4 groups of 15 each according to the different anti-erosion toothpastes used and distilled water was used as control. All specimens were stored in distilled water (pH 6.8) at room temperature for 24 hours. Baseline measurements of surface roughness {Sa = Arithmetic mean height} in micrometer (µm) were recorded (Testing Phase One - T1). Table 2 shows distribution of different groups according to the restorative materials, the different anti-erosion toothpastes used and distilled water.

M`aterial/Manufacture Information/Lot #	Anti-erosion/ Manufacture Information/Lot #
Resin Composite - Filtek Z250 XT (3M ESPE, St. Paul, MN, USA) LOT# N624367	SensodynePronamel - Glaxo Smith Kline Company LOT# 41522KWA
Resin ModifiedGlass ionomer - GC Fuji II LC GC Corporation Tokyo, Japan LOT# 150303A	Biorepair - Coswell, Spa 40050 Funo/Italy LOT# 413751014
ConventionalGlass ionomer - Ketac Fil Plus Aplicap (3M ESPE, St. Paul, MN, USA) LOT# 520043	Regenerate - PT Unilever Indonesia tbk. RungkutIndustry IV/5-11 LOT# 42038CA

Table 1: Different anti-erosion toothpastes and the restorative materials used in this study.

All specimens according to the groups in Table 2 were brushed manually with water without anti-erosion toothpastes (control) or brushed manually with the different anti-erosion 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 then rinsed using distilled water for five minutes and blotted dry with tissue paper before repeating measurement of surface roughness similar to baseline measurement (Testing Phase Two - T2).

Restorative Material	Different Anti-erosion Toothpastes /Distilled Water	Number of Specimens
Filtek™ Z250 XT	C1=Distilled Water	15
	C2=SensodynePronamel	15
	C3=Biorepair	15
	C4=Regenerate	15
GC Fuji II LC®	F1=Distilled Water	15
	F2=SensodynePronamel	15
	F3=Biorepair	15
	F4=Regenerate	15
Ketac Fil Plus Aplicap	K1=Distilled Water	15
	K2=SensodynePronamel	15
	K3=Biorepair	15
	K4=Regenerate	15

Table 2: Distribution of different groups according to materials used.

Optical Profiler Analysis - The surface roughness of restorative materials was analyzed with a 3D optical noncontact surface profiler (Contour Gt-K1 optical profiler, Bruker Nano, Inc., Tucson, AZ, USA) based on noncontact scanning interferometer to evaluate roughness of each surface. The objective standard camera 1.0X has a magnification 5X. The profile meter scanned area (3 measurements in different directions) were approximately 1.3 x 1.0 mm2 and were situated at the center of each surface. Multi-Core Processor with Vision64 Software for accelerated 3D surface measurement and analyses were used for image transfer (Bruker Nano Surface Division, Inc., Tucson, AZ, USA).The 3D profilometer scan each specimens and generate measurements of different parameters which is recorded by the software. The recorded measurements of surface roughness {Sa = Arithmetic mean height} in micrometer (µm) was used in this study.

Two-way Analysis of Variance (ANOVA) and paired t-test were used to compare and evaluate interactions between the materials and different groups. All statistical analyses were set with a significance level of $p<0.05$. The statistical analysis was carried out with SPSS Version 16.0 (SPSS Inc. Released 2007. SPSS for Windows, Chicago, SPSS Inc., Ill).

Results

The mean (+SD) of surface roughness (Sa) in micrometer (µm) of Filtek Z250 XT, GC Fuji II LC and Ketac™ Fil Plus Aplicap at baseline after finishing and polishing (T1) are given in Table 3. The highest Sa at T1 was observed in Ketac Fil Plus Aplicap(0.73+0.45) followed by GC Fuji II LC (0.32+0.09) then Filtek Z250 XT(0.16+0.02).

Comparisons between the groups of (T2) to the groups of baseline after finishing and polishing(T1) for Filtek Z250 XT, GC Fuji II LC and Ketac Fil Plus Aplicap are shown in Table 3. For Filtek Z250 XT, there was statistically significant difference between T2 and T1 in surface roughness (Sa)of the specimens brushed with distilled water($p=0.014$), Sensodyne Pronamel($p=0.003$), Biorepair ($p=0.0001$), and Regenerate ($p=0.0001$). For the GC Fuji II LC, there was statistically significant difference between T2 and T1 in surface roughness (Sa)of the specimens brushed withdistilled water($p=0.005$), Sensodyne Pronamel ($p=0.001$), Biorepair(p=0.001), and Regenerate (p=0.0001). For Ketac Fil Plus Aplicap, there was statistically significant difference between T2 and T1 in surface roughness (Sa) of the specimens brushed with distilled water (p=0.002), Biorepair (p=0.001), and Regenerate(p=0.001). There was no statistically significant difference in surface roughness for Sensodyne Pronamel between T2 and T1(p=0.209).The ANOVA showed a statistically significant difference in the Filtek Z250 XT groups (p=0.006) but not in GC Fuji II LC groups (p=0.444) nor Ketac Fil Plus Aplicapgroups (p=0.166).

Restorative Material	Different Anti-Erosion Toothpastes/ Distilled Water	Mean (Std. Deviation)
Filtek Z250 XT	Water	0.060* (0.082)
	Sensodyne	0.134* (0.141)
	Biorepair	0.059* (0.0323)
	Regenerate	0.061* (0.038)
GC Fuji II LC	Water	0.206* (0.237)
	Sensodyne	0.192* (0.185)
	Biorepair	0.212* (0.186)
	Regenerate	0.174* (0.138)
Ketac Fil Plus Aplicap	Water	0.738* (0.762)
	Sensodyne	0.240 (0.705
	Biorepair	0.989* (0.891)
	Regenerate	1.161* (1.022)

Table 3: The mean and standard deviation of surface roughness (Sa) of all tested materials at baseline after finishing and polishing (T1).

Statistical analysis was completed to do multiple comparisons between the groups within Filtek Z250 XT, GC Fuji II LC and Ketac Fil Plus Aplicap. For Filtek Z250 XT, there was statistically significant difference in surface roughness between distilled water and Sensodyne Pronamel (p=0.005) and between SensodynePronamel and Regenerate (p=0.036). There was no statistically significant difference in surface roughness between different surface treatments for GC Fuji II LC(p=0.942) and Ketac Fil Plus Aplicap (p=0.447).

Discussion

The present study investigated the surface roughness of three restorative materials. Nanohybrid RC (Filtek Z250 XT), RMGI (GC Fuji II LC) and conventional GI (Ketac Fill Plus Aplicap) after finishing and polishing and after being subjected to brushing with different anti-erosion toothpaste. The null hypothesis was rejected, as there was a difference in the effect of the anti-erosion toothpastes tested on surface roughness of the tested tooth-colored restorative materials.

Surface roughness of different restorative materials governs the quality, color and performance of materials in the oral cavity. Roughness could also worsen buildup of plaque and diminish longevity and esthetics of the restorations [11]. Experimental data demonstrated that high surface roughness of restorative materials is correlated to presence of more biofilm on its surface [12]. The surface roughness influences the biofilm formation and maturation on restorative materials and a more complex biofilm can be formed on a rougher substrate rapidly [13,14]. The aim is to produce restorations with smooth surfaces without irregularities which result in improved esthetics and minimal plaque accumulation [15,16]. There is no agreement about reference data on the limit roughness below which the bacteria would not adhere [17]. The most commonly mentioned limit of surface roughness (Ra) is below 0.2μm for adherence of dental biofilm [12]. It could be more accurate to say, that it depends on the bacteria species [12,18,19]. It is important to emphasize that rough surfaces favor bacterial adhesion and biofilm formation on the teeth and restorations, which can further cause secondary caries, gingival and periodontal diseases [12,18]. Although comparisons between surface roughness data of other investigations have to be taken with thoughtfulness due to differences in methods and settings of, surface analysis as well as test materials. It is not possible to compare roughness values obtained with contact profilometer along one line (Ra) of the specimen with those values obtained with the non-contact optical interferometers as Surface Area (Sa).

The lower surface roughness values of resin composite can be explained by material filler composition. This material is a submicron hybrid resin composite, filled with nanometer size particles, from which some are dispersed and others create nanoclusters, as secondary formed fillers [20]. The size of these nanoclusters can range from about 0.6 to 10 μm [20]. Mylar strips and celluloid crowns are usually applied as matrices for shaping restorative materials, which more likely require no further surface finishing [12]. It was suggested using polyester strips against resin composite to produce the best smooth surface [12] which justified its application in the present study. This is supported by another study, which reported significantly higher surface roughness for polished resin composite compared to the one polymerized against Mylar strips [21]. Studies have investigated different polishing methods on surface roughness and many have reported that none of these methods could mimic the surface smoothness initially created by a Mylar strip [22,23]. However, another study observed this phenomenon only for one resin composite material, whereas other resin composites showed no significant differences in surface roughness between the surfaces polished with silicone carbide paper and those polymerized against Mylar strips [15,22].

As measurement of surface roughness determined by the method used, the research protocol for roughness is vital [24].

The assessment of roughness using Scanning Electron Microscope (SEM) is subjective and descriptive as well as unreliable for quantitative analysis [25]. A contact profilometer with a stylus that moves in line is used for the quantitative investigation of roughness and may induce misconception due to holes on the surface. Other instruments are used to assess roughness at higher resolution and over a wider area such as non-contact optical interferometers and Atomic Force Microscopes (AFM) [26]. In this study, the optical interferometer noncontact profilometer was used to measure surface roughness. Compared with a stylus profilometer, the optical interferometer noncontact profilometer is faster, nondestructive, and allow repeatability. In addition, it provides a larger field and does not need sample preparation in comparison with AFM. There are few reports of using optical interferometer noncontact profilometer to determine the surface roughness of restorative materials.

During tooth brushing, the toothpaste is quickly diluted by saliva. In the present study, the toothpastes were not diluted prior to application according to the manufacturers' directions.A study investigated the influence of two anti-erosive toothpastes on surface roughness of two resin composites (Filtek Supreme Ultra Universal Restorative and TPH Spectrum Restorative), one compomer (Dyract Extra), and two conventional glass ionomer restorative materials (Ionofil U and SDI). It was revealed that the surface roughness of the Filtek Supreme, TPH, Dyract and Riva Self cure materials were not affected by the application of either toothpastes. However, surface roughness of manually mixed glass ionomer (Ionofil U) was significantly increased when brushed with both Tooth Mousse and Pronamel paste. The authors conclude that neither Pronamel nor Tooth Mousse caused a significant change on the surface roughness of tested restorative materials except Ionofil U. It was significantly increased following brushing with either paste [4].

In the present study the surface roughness of two of the materials was not measured before finishing and polishing with Sof-Lex system. However, another study showed enhancement of the surface roughness of RC while the conventional GI(KetacFil Plus Aplicap) after finishing and polishing showed increased in the surface roughness [27,28]. Effective finishing instruments should have cutting particles harder than the filler materials. If not the polishing instrument will only remove the matrix and leave the particles protruding from the surface, which gave rougher surface. In general, a statically significant difference on surface roughness after brushing with water or different anti-erosion toothpaste was recorded in this present study. The lowest surface roughness readings after brushing the Filtek Z250 XT we rerecorded when the specimens were brushed with water then Regenerate, and Biorepair while the highest surface roughness was recorded with the use of Sensodyne Pronamel. Regarding GC Fuji II LC the lowest values of surface roughness were recorded after brushing with Regenerate toothpaste then water, and Sensodyne Proenam elrespectively while the highest surface roughness readings were recorded when brushed with Bio repair toothpaste. For the Ketac Fil Plus Aplicap, Regenerate toothpaste has the lowest effect on surface roughness then Sensodyne Pronamel, water respectively while Biorepair toothpaste caused the highest increase of the surface roughness.

The type of the restorative materials is determining factor on surface roughness values since the composition, shape and size of the particles play an important role of the behavior of the restorative material study. A study demonstrated that toothbrush abrasion of resin composite materials differs according to the type of resin composite used [29]. In addition, the composition of the toothpaste has a crucial rule in the alteration of the surface roughness of dental restorative materials. An investigation reported that the higher the relative dentin abrasively of toothpaste the higher the surface roughness and wear of the dental materials. Another factor which has a rule in increasing the surface roughness is the type of the toothbrush and pressure used when brushing [30]. Our study was only short term for 15 days and the results may be difference if longer brushing time was tested. However, a study evaluated the effect of brushing time and dentifrice abrasiveness on color change and surface roughness of resin composites concluded that the longer the brushing time and dentifrice abrasiveness, the greater the color change of the nanofilled resin composite but the surface roughness was not influenced by dentifrice abrasiveness [31]. Another study evaluated surface properties of universal and flow able nanohybrid composites after simulated tooth brushing reported that the lowest surface roughness was for the flow able nanohybrid composites after toothbrush abrasion [32]. An investigation assessed longitudinal evaluation of simulated tooth brushing on the roughness of microfilmed, micro hybrid and nanofilled resin-based composites reported that tooth brushing increased the roughness of the three RBCs [33].

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 anti-erosion tooth pastes in vivo. This may be different if we used the tested anti-erosion 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 [34]. However, in this in vitro study, standardization of experimental conditions was advantage and the results demonstrated a clear correlation between surface roughness of the tested restorative materials and anti-erosion toothpastes.

Conclusions

Under the experimental conditions, we concluded:

1. Short term brushing for 15 days with anti-erosion toothpastes resulted in significant changes of the surface roughness of Filtek Z250XT, GC Fuji II LC and Ketak Fil plus Aplicap which indicates that roughness depending on the anti-erosion toothpastes and the restorative material used.
2. The toothpaste that caused the highest change of surface roughness on Filtek Z250XT was Sensodyne Pronamel and for the GC Fuji II LC and Ketak Fil Plus Aplicap was Biorepair.
3. In general, resin composite/Filtek Z250XT showed the smoothest surface before and after application of anti-erosion toothpastes.

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