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The Effect of Home Bleaching Agents on the Surface Roughness and Fracture Toughness of Composite Resin Materials

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Abstract

Aim and Objective: This study determined the effect of home bleaching agents on the surface roughness and fracture toughness of composite resin materials.

Methodology: 70 specimen of nanohybrid resin composite (Filtex supreme plus (Z 350) and Esthet x) were exposed to two home bleaching gels (10% and 20% carbamide peroxide CP) were prepared. Thirty five specimen of each group were fabricated randomly divided into 6 subgroup as follows: Group 1 Filtex supreme plus (Z 350) (N=35):Subgroup 1 (n=5)-control group (distilled water), subgroup 2 (n=15)-treated with 10% CP, subgroup 3 (n=15)-treated with 20% CP. Group 2 Esthet x (n=35): subgroup 1 (n=5)-control group (distilled water), subgroup 2 (n=15)-treated with 10% CP, subgroup 3 (n=15)-treated with 20% CP for 8 hrs/day. All treatment was conducted at room temperature and fresh gel applied and rinsed off daily for 2 weeks. For bleached group, the specimens were stored in distilled water during hiatus period. All specimen were subjected to roughness testing (Ra) at 0 day, 1 day and 14th day using the profilometer and then subjected to three point bending test for fracture toughness. Then all the data were send for statistical analysis.

Results: 1) Both nanohybrid composite showed minimal surface roughness values as they are below the critical threshold of 0.2 mm which is not clinically significant.

2) The surface roughness value of Filtex Z350 is lower than Esthet X but not statically significant ($p<0.05$).

3) Bleaching had a significant effect in increasing the fracture toughness value on Filtek Z350 but not on the Esthet X composite.

Conclusion: Within the limitation of the present study it was concluded that the practice of home bleaching after placement of the composite restoration does not compromise on surface roughness and the fracture toughness property of the resin composites and does not need its replacement.

Keywords: Home bleaching; Carbamide peroxide; Nanohybrid composites; Surface roughness; Fracture toughness

Introduction

Aesthetic appearance of teeth has been a major concern for patients. Tooth discoloration is a common problem affecting people of various ages and it can occur in both primary and permanent teeth [1]. With the growing awareness of the esthetic options available, there is a greater demand for solutions to unsightly problems such as food staining, fluorosis and tetracycline staining [2].

Before the mid 1980's various difficult, technique sensitive and potentially invasive procedures such as veneers and crowns were used. In recent years the demand for esthetic dentistry has grown, bleaching teeth is one of the effective, comparatively safe, conservative treatments in dentistry [3]. Various bleaching agents used include superoxol that contains 30% hydrogen peroxide and sodium perborate for non-vital bleaching. However these treatments have been reported to cause an increased incidence of cervical root resorption [4].

In office bleaching, a bleaching agent gel of 35-38% hydrogen peroxide is applied at the tooth surface and allowed to remain on the teeth for 30-45 min. A chemically activated bleaching agent, or usually a visible light curing lamp, is used to enhance the bleaching process [5]. However, these treatments are harmful to the soft tissue because of their caustic higher concentration.

Therefore the introduction of carbamide peroxide by Haywood and Heymann [6] in-home bleaching has created resurgence in the area of bleaching primarily because of its relative ease of applications, the safety of the material used , the lower cost, its general availability to all socio- economic classes of patients, and the high percentage of successful treatment [7].

Tooth-colored restorative materials, especially composite resin, have become an important part of modern dentistry. Nano composite resin studies have shown that they have high translucency, high polish ability and its retention, similar to microfill composites, while maintaining the physical properties and wear resistance equivalent to those of several hybrid composites [8].

The effect of bleaching on dental restorative materials has been reviewed recently [7]. Bleaching agents may change the surface morphology, as well as the chemical and physical properties of composite resins. Chemical softening from bleaching may affect the clinical longevity of the composite restorations [9].

When resin composite restorations are clinically used, they are frequently removed after bleaching due to possible negative physical-mechanical consequences [5,9] and require restoration replacement which is expensive [7,10]. The consequences of bleaching of resin-based materials can vary according to resin and bleaching gel compositions, frequency and duration of exposure. Alteration of fracture toughness and surface roughness are commonly used to analyze the possible negative effect of bleaching products [7].

Surface roughness has been a major concern for researchers and clinician, as an increase in superficial roughness is clinically relevant, and irrespective of etiological factor, increase in roughness results in accumulation of food residues and formation of biofilms, leading to periodontal tissue disease [11,12]. Studies have shown that initial colonization of bacteria starts from surface irregularities where bacteria are protected against shear forces [13]. They have also shown that restorations with rough surfaces increased glucan adhesion and bacteria colonization [14].

Fracture toughness is the measure of a material's ability to resist crack propagation. It is considered to be a reliable indicator of the ability of dental materials to resist failure under load [15]. Cho, et al. [16] found that bleaching had a significant effect on increasing the values of fracture resistance for the resin Filtek Supreme Plus, but not for the other resins.

So, the following study was conducted to compare the effect of home bleaching (10% and 20% carbamide peroxide) on the surface roughness and fracture toughness of the composite resin material.

The null hypothesis considered in this study was that there is no difference between the fracture toughness and surface roughness of different resin composite materials after bleaching.

Methodology

Seventy specimen of nanohybrid resin composite (Filtex supreme plus (Z 350) and Esthet x) were exposed to two home bleaching gels-

Carbamide Peroxide CP 10%-Opalescence PF Ultradent, South Jordan, UT, USA [B4K8T]

Composition: 10% Carbamide Peroxide, Sodium Fluoride 0.25%, Potassium Nitrate 0.5%

Carbamide Peroxide CP 20%-Opalescence PF Ultradent, South Jordan, UT, USA [B4K8T]

Composition: 20% Carbamide Peroxide, Sodium Fluoride 0.25%, Potassium Nitrate 0.5%

Two brands of nanofilled resin composites were evaluated: Filtek Supreme Plus (FSP, 3M ESPE) and Esthet-X (ESX, Dentsply, York, PA, USA). Shade A2 was used for both resin composites in the study. Two concentrations of carbamide peroxide bleaching agents were tested: Opalescence PF 10% (OPF10), 20% (OPF20) (Ultradent, South Jordan, UT, USA).

The groups 1 & 2 composite cylindrical blocks were prepared by applying 2 mm increments and was light cured in three overlapping segments using a standardized plastic mould of 6 mm length and 6 mm diameter. The samples were light cured (LED) (IvoclarVivadent) as per manufacturer's instructions. The samples were polished with medium, fine, and superfine disks (ShofuInc, Kyoto, Japan) on a slow hand piece, in accordance with the manufacturer's instructions. After polishing, samples were subjected for 2 min to ultrasonic cleaning with distilled water to remove any surface debris. All samples were stored in distilled water at room temperature for 24 h before the initiation of any procedure.

All samples were then divided into 2 test groups (n=35). 5 samples of each of the 2 different resin composite samples were selected for baseline surface roughness measurements (with the mechanical surface profilometer-Mitutoyo Japan)) and fracture toughness test (Universal testing machine-LLOYD instruments, LR 50K) as control groups.

Subsequently, Group 1 (n=35) further divided into 3 subgroups.

SUBGROUP 1: Control (n=5) distilled water

SUBGROUP 2: 10% Carbamide Peroxide (n=15)

SUBGROUP 3: 20% Carbamide Peroxide (n=15)

Subsequently, Group 2 (n=35) further divided into 3 subgroups.

SUBGROUP 1: Control (n=5) distilled water

SUBGROUP 2: 10% Carbamide Peroxide (n=15)

SUBGROUP 3: 20% Carbamide Peroxide (n=15)

Upon the commencement of the experiment, the specimens from subgroup 1 (control group) of both the groups were stored in distilled water at 370 C for two weeks. The specimens from subgroup 2 were treated with 10% carbamide peroxide for 8 hrs/day for two weeks and subgroup 3 were treated with 20% carbamide peroxide for 8 hr/day for two weeks.

Fresh bleaching gels were applied on all the surfaces of samples. At the end of the bleaching procedure, the treated specimens were washed under running distilled water till all remnants removed from surface. Then they were placed in fresh distilled water until the next application. The control groups were stored in distilled water during the experiment period. The distilled water was replaced every day.

The entire specimen was subjected to surface roughness testing (Ra-roughness average) at 0 day, 1st day and 14th day of the treatment using mechanical profilometer (Mitutoyo, Kanagawa, Japan). For each sample of all the groups, three randomized readings were performed on the challenged surfaces after each bleaching protocol. Margins and visible irregularities were avoided.

Then all the specimens were stored in distilled water for 24 h at 37 degree C before subjecting for fracture toughness.

To assess the fracture toughness, all the specimen were subjected to a three point bending test in an Instron Universal testing machine(LLOYD Instruments, LR 50K) 24 h after 2 weeks period. The results were subjected to statistical analysis.

Results

The results were calculated and analyzed by Analysis of variance (ANOVA) and Post hoc Tukey test was used for pair wise comparison of groups, Student t test (two tailed, dependent) was used to find the significance of study parameters on continuous scale within each group. Statistical significance was set as p ≤ 0.05.

Surface Roughness Analysis (Ra value in µm)

On comparing group 1 and group 2 (Figure 1-3) (Table 1)

Before treatment: surface roughness value is minimal in both groups (1 and 2) within all subgroups (1,2,3)

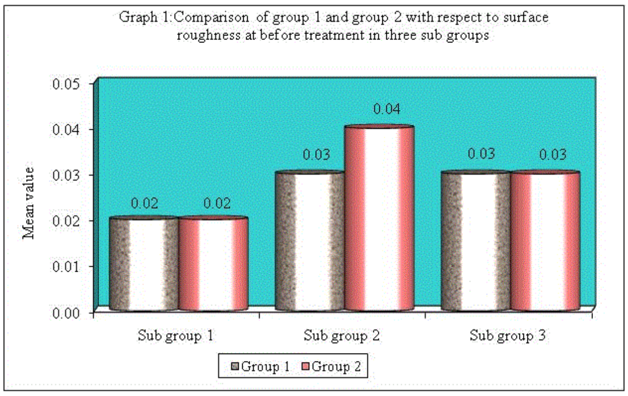

Figure 1: Comparison of group 1 and group 2 with respect to surface roughness at before treatment in three sub groups

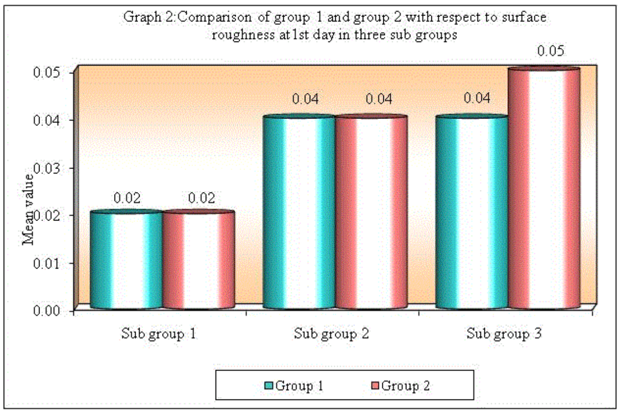

Figure 2: Comparison of group 1 and group 2 with respect to surface roughness at 1st day in three sub groups

After treatment on 1st day:

1) Subgroup 1 (Control group): shows minimal roughness value (0.02) in both groups (1 and 2).

2) Subgroup 2 (10% CP): similar value is seen (0.04) in both group (1 and 2) and on comparing with subgroup 1 (0.02), both groups (1 and 2) shows more roughness value but not statistically significant (p<0.05)

3) Subgroup 3 (20% CP): group 2 (0.05) shows more roughness value compared to group 1 (0.04) but no statistically significant (p<0.05). On comparing with subgroup 1 (0.02), both groups (1 and 2) shows more roughness but not statistically significant (p<0.05).

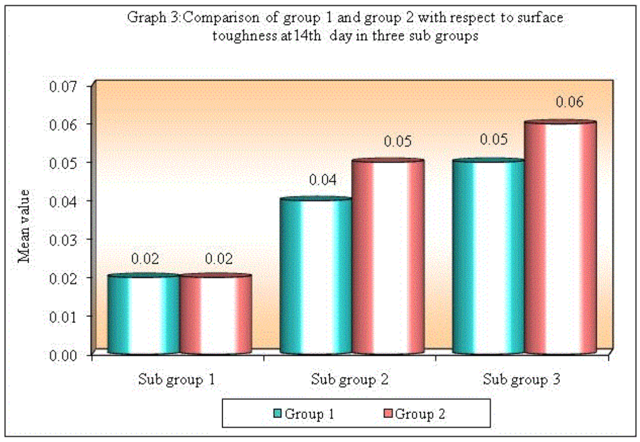

Figure 3: Comparison of group 1 and group 2 with respect to surface toughness at 14th dat in three sub groups

Sub groups	Time point	Main groups	Mean	SD	t-value	P-value
Sub group 1	Before	Group 1	0.02	0.01	0.4472	0.6666
		Group 2	0.02	0.01		
	1st day	Group 1	0.02	0.01	0.4472	0.6666
		Group 2	0.02	0.01		
	14th day	Group 1	0.02	0.01	0.4472	0.6666
		Group 2	0.02	0.01		
Sub group 2	Before	Group 1	0.03	0.01	0.7184	0.4785
		Group 2	0.04	0.01		
	1st day	Group 1	0.04	0.01	0.2963	0.7692
		Group 2	0.04	0.01		
	14th day	Group 1	0.04	0.02	1.0493	0.3030
		Group 2	0.05	0.01		
Sub group 3	Before	Group 1	0.03	0.01	-0.7135	0.4814
		Group 2	0.03	0.01		
	1st day	Group 1	0.04	0.01	1.0583	0.2990
		Group 2	0.05	0.01		
	14th day	Group 1	0.05	0.01	-1.5110	0.1420
		Group 2	0.06	0.01		

Table1: Comparison of Group 1 and Group 2 in Sub Group 1, 2, 3 With Respect To Surface Roughness at Before Treatment, 1st Day and 14th Day by T Test

After treatment on 14th day:

1) Subgroup 1 (Control group): shows minimal roughness value (0.02) in both groups (1 and 2).

2) Subgroup 2 (10% CP): group 2 (0.05) shows higher roughness value than group 1 (0.04) but not statistically significant (p<0.05) and on comparing with subgroup 1 (0.02), both groups (1 and 2) shows more roughness value but not statistically significant (p<0.05).

3) Subgroup 3 (20% CP): group 2 (0.06) shows more roughness value compared to group 1 (0.05) but no statistically significant (p<0.05). On comparing with subgroup 1 (0.02), both groups (1 and 2) shows more roughness but not statistically significant (p<0.05).

Fracture Toughness Analysis

On comparing group 1 and 2: (Figure 4) (Table 2)

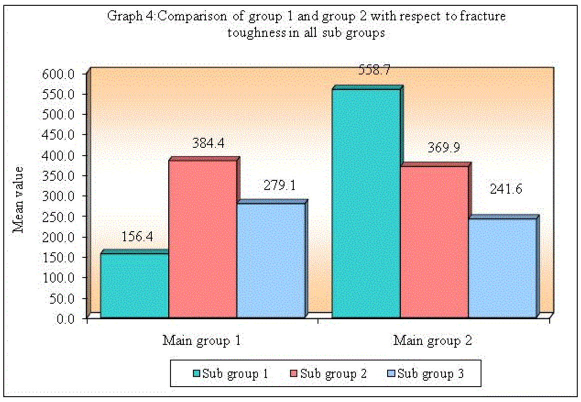

Figure 4: Comparison of group 1 and group 2 with respect to fracture toughness in all sub groups

Sub groups	Main groups	N	Mean	SD	t-value	P-value
Sub group 1	Group 1	5	156.38	42.69	-9.6006	0.0000*
	Group 2	5	558.68	83.41		
Sub group 2	Group 1	15	384.39	55.77	0.7082	0.4847
	Group 2	15	369.89	56.43		
Sub group 3	Group 1	15	279.05	31.78	2.0252	0.0525
	Group 2	15	241.56	64.26		

*p<0.05

t test: student t test

Table 2: Comparison of Group 1 and Group 2 with Respect to Fracture Toughness in all Sub Groups by T Test

1) Subgroup 1 (Control group): Group 2 shows more toughness value (558.6 MPa) than group 1(156.3 MPa) and is statically significant (p<0.05).

2) Subgroup 2 (10% CP): Group 1 shows more toughness value (384.3 MPa) than group 2 (369.8 MPa) but not statically significant (p<0.05).

3) Subgroup 3 (20% CP): Group 1 shows more toughness value (279 MPa) than group 2 (241.5 MPa) but not statically significant (p<0.05)

Discussion

The effect of bleaching on dental restorative materials has been reviewed recently [7]. Bleaching agents may change the surface morphology, as well as the chemical and physical properties of composite resins. Chemical softening from bleaching may affect the clinical longevity of the composite restorations [10]. Softening of the composite materials by chemicals in the bleach is believed to occur in vivo, contributing to resin wear in both stress- bearing and non-stress bearing areas.

In most surface roughness studies, mechanical profilometer was used to determine the surface roughness as a Ra value [17,18] and a home bleaching regimen involving 8 hrs/day was adopted in this study as clinically relevant.

The result of the surface roughness testing in present study revealed that in group 1 and group 2, Ra value increases after bleaching treatment on 1st day and 14th day in both groups.

The reason for increase in surface roughness after bleaching can be explained by previous studies which revealed that carbamide peroxide bleaching gels may lead to slight roughness of resin-based composites although it may have no clinical significance [19]. It has been found that bleaching agents impair the surface integrity, affecting the penetration depth of the bleaching agent. Chemical softening from bleaching may affect the clinical longevity of the composite restoration [20]. The present study revealed that both composites tested underwent surface alterations of their superficial surface after bleaching. Interestingly, some studies have reported an increase [21], decrease [19], or unchanged [22] composite surfaces after applying carbamide peroxide gels for varying time periods. Authors suggested that the surface changes could have been caused by complex interactions within multi-component bleaching products. Roughening was suggested to result from the loss of matrix, rather than filler particles [23].

Some aspect of this chemical process might accelerate the hydrolytic degradation of resin composites as described by Söderholm [23]. Another aspect may be that hydrogen peroxide and free radicals have an effect on the resin-filler interface and cause a filler-matrix debonding, this may cause microscopic cracks, leading to an increase in surface roughness [18].

In the present study, group 2 (Esthet X) showed more surface roughness compared to group 1 (Filtex Z350). Filler size is one of the factors that determine the surface roughness and polishability of the restorative materials [24]. The large particle size in composites can enhance microporosity in the structure [25]. This can explain the reason for least change in surface topography of group 1 after bleaching as compared to group 2 as it has smallest filler particle size (20 nm). The filler size of group 2 is 0.6–0.8 μm and this large filler size explains its rougher surface after bleaching [20]. But the results also reveal the minimal clinical surface alteration in both groups after bleaching. Study by Quirynen [15] demonstrated that rougher surfaces accumulated more plaque. For surface roughness below 0.2 μm no significant effect on plaque accumulation and composition was found. This led to the suggestion of a 0.2 μm "threshold Ra". In the present study, the surface roughness for both composites tested has readings below than 0.2 μm. Bollen et al. [26] reported that Ra above 0.2 μm results in an increase in plaque accumulation and higher risk for caries and periodontal inflammation. According to Chung, when Ra was lower than 1 μm the surfaces were visibly smooth. Therefore, both of the composites surfaces evaluated after bleaching have demonstrated a smooth surface, which from the clinical point of view, presents no risk of plaque accumulation [27].

Fracture toughness is the measure of a material's ability to resist crack propagation. It is considered to be a reliable indicator of the ability of dental materials to resist failure under load.

Even though all the resin composites included in the current study utilized nanofiller technology, there were significant differences in the fracture toughness values (KIc). This result supported data from the past that the materials categorized in the same group as nano-particle resin composites do not always have similar physical and mechanical properties. Previous studies reported various three-point flexural strength data within the same brands of resin composite [16].

The results of the current study showed a significant ($p<0.05$) increase in fracture toughness values in the group 1 (Filtex Z350) after bleaching but not in the other group 2 (Esthet X). The most significant improvement in fracture toughness values was seen when bleached with 10%, followed by 20%. It is interesting to see that group 1 had the lowest fracture toughness values in the control groups but had significantly improved strength after bleaching. When comparing the fracture toughness value of resin composites after bleaching with 10%, group 1 was significantly stronger. Our results are similar to study by Cho, et al. [16] where the fracture resistance of four nanoparticle composite resins (Filtek Supreme Plus, Tetric EvoCeram, Premise and Esthet-X) was tested after exposure to four different concentrations of bleaching gels (Opalescence PF at 10%, 20%, 35% and 45%). Those authors found that bleaching had a significant effect on increasing the values of fracture resistance for the resin Filtek Supreme Plus, but not for the other resins. A review on the effects of external bleaching on restorative materials and found that when it comes to composite resin, several studies have shown that bleaching agents have the potential to alter the physical properties of the restorations, but not yet demonstrated the clinical relevance of these changes [16].

The low values of fracture toughness of group 1 in a control group may suggest incomplete polymerization. This result is consistent with the peroxides of the bleaching agent acting as an additional initiator of the polymerization of the matrix. Increased initiation would be expected to increase the average molecular weight of the resin matrix, enhancing its mechanical properties. Initial maximal polymerization of the control group, in group 2 resulted in no change of fracture toughness values after bleaching. The leaching of fillers from resin composites has been recognized as occurring within aqueous environments. It could be hypothesized that increasing the concentration of the peroxide is associated with a degradation process that would result in decreasing fracture toughness [23].

Conclusions

Within the limitation of the present study it was concluded that:

1) Both nanohybrid composite showed minimal surface roughness values as they are below the critical threshold of 0.2 mm which is not clinically significant.

2) The surface roughness value of Filtex Z350 is lower than Esthet X but not statically significant ($p<0.05$).

3) Bleaching had a significant effect in increasing the fracture toughness value on Filtek Z350 but not on the Esthet X composite.

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