

Research Article

Effect of Dental Bleaching on the Fracture Toughness of Silorane and Methacrylate-Based Composite Resins

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Citation: Moghadam FV, Oghazian S, Ghavamnasiri M, Chasteen JE, Majidinia S (2016) Effect of Dental Bleaching on the Fracture Toughness of Silorane and Methacrylate-Based Composite Resins. Dent Adv Res 1: 104. DOI: 10.29011/2574-7347.100004

Received: 3 March, 2016; **Accepted:** 30 March, 2016 **Published:** 13 April, 2016

Abstract

Objectives: To compare the fracture toughness (K_{Ic}) of silorane and dimethacrylate-based composite resins after bleaching with 15% Carbamide peroxide.

Methods and materials: Twenty bar-shaped specimens of each of three composite resin materials were tested in this *in vitro* study. These materials included two dimethacrylate-based composite resin materials: a nanofilled composite (Filtek Z350™) and a microfilled composite (Heliomolar™) as well as a silorane-based composite (Filtek P90™). The bar-shaped specimens were made to conform to ASTM guidelines for a single-edge-notch bar-shaped specimen. The composite specimens were divided into control and test groups. The test specimens were treated with 15% Carbamide peroxide for approximately 8 hours a day for 14 days. Using an Instron Universal Testing Machine testing machine, all specimens were then subjected to a three point bending test at a crosshead speed of 5mm/min. Fracture toughness values were analyzed using ANOVA and Tukey tests ($\alpha=0.05$).

Results: After bleaching, the fracture toughness values of Filtek Z350™ (0.52 ± 0.08) and Filtek P90™ (0.58 ± 0.04) showed no significant difference ($p=0.744$ and $0.062 > 0.05$). Although the fracture toughness of Heliomolar™ (0.46 ± 0.03) increased significantly after bleaching ($p=0.004 < 0.05$), it showed less K_{Ic} compared with the other composites both before ($P=0.000$) and after ($P=0.002$) bleaching.

Conclusion: Within the scope of this study, the microfilled composite (Heliomolar™) was the only composite tested that demonstrated an increase of fracture toughness following the exposure to a 15% carbamide peroxide bleaching gel.

Keywords

Bleaching; Dimethacrylate-based composite; Fracture toughness silorane-based composite

Introduction

Tooth bleaching has become popular in dentistry because it is considered to be an effective and noninvasive treatment for

discolored teeth [1]. Recently, a new silorane-based composite resin was introduced with a distinctive polymerization characteristic that reduces polymerization shrinkage by as much as 1% [2].

The silorane matrix is formed by the cationic ring-opening polymerization of silorane monomers. Even though silorane-based composites have higher values with regard to flexural strength, fracture toughness and color stability than other composite formulations, they demonstrate lower compressive strength and translucency values [3].

Fracture toughness is considered to be a reliable indicator of the ability of dental materials to resist failure under load [4]. A Mode I fracture is a single crack created under normal tensile stress applied perpendicular to the direction of the resultant crack. The Mode I fracture toughness value is called the K_{Ic} [4]. Various *in vitro* studies have been done on the effect of bleaching agents on the surface hardness [5,6], surface roughness [7,8], color stability [9,10], and flexural strength [2] of composite resins. However, only one previous study was conducted to determine the effect of different concentrations of carbamide peroxide (10%, 20%, 35% and 45%) on the fracture toughness of nanofilled composite resins (Tetric™ Evoceram™, Filtek Supreme Plus™, Esthet™ and Premi™). Results showed that vital bleaching could significantly increase the fracture toughness of Filtek Supreme Plus™, but other composite resins were not affected under different concentrations of carbamide Peroxide [11].

Fracture toughness is one of the most important mechanical properties of composite materials because it could be related to their hardness and flexural strength [2,12,13]. Because of this possible relationship, the aim of this study was to determine the effect of 15% carbamide peroxide on the fracture toughness of three composite resins. Two were dimethacrylate-based, (Filtek Z350 XT™ and Heliomolar™) and the third was a silorane-based (Filtek P90™) composite resin material.

The null hypothesis of study was that the bleaching agent had no effect on the fracture toughness of the composite resins tested.

Methods and Materials

According to Sasaki et al., study, twenty bar-shaped specimens of each of three composite resin materials were tested in this *in vitro* study. These materials included two dimethacrylate-based composite resin materials: a nanofilled composite (Filtek Z350™, 3M ESPE, Minneapolis, MN, USA) and a microfilled composite (Heliomolar™, Ivoclar Vivadent, Schaan, Liechtenstein) as well as a silorane-based composite (Filtek P90™, 3M ESPE, Minneapolis, MN, USA). Shade A2 was selected for all resin composites in this study.

The bar-shaped specimens were fabricated in a metal mold to conform to ASTM guidelines for a Single-Edge-Notch (SEN)

bar-shaped specimen with dimensions of 25×5×2.5 mm and a crack 2.12 mm in length (Figure 1).



Figure 1: Metal mold for preparation of the bar-shaped composite resin specimens.

Paraffin was used as a neutral lubricating material before placing the uncured composite material in the mold to facilitate specimen removal after polymerization. The bottom and top surfaces of specimens were covered with a clear polyester strip and each surface was photo-activated for 40 seconds, using a Blue phase 16i light curing unit (Ivoclar Vivadent, Amherst, NY). The light intensity was verified with a radiometer to ensure a power output of 800 mW/cm². After polymerization, the composite samples were polished using 800 grit silicon carbide abrasive papers.

Each group of composite specimens types (n=20) was divided into two subgroups (n=10) according to whether the subgroup was treated with the bleaching gel or not. Specimens representing the control subgroups were not subjected to the bleaching process and were stored in distilled water at 37°C for 14 days in incubator. The test subgroup specimens were immersed in 15% Carbamide peroxide gel (Opalescence PF, Ultradent, South Jordan, UT, USA) for about 8 hours per day for 14 days (Figure 2).

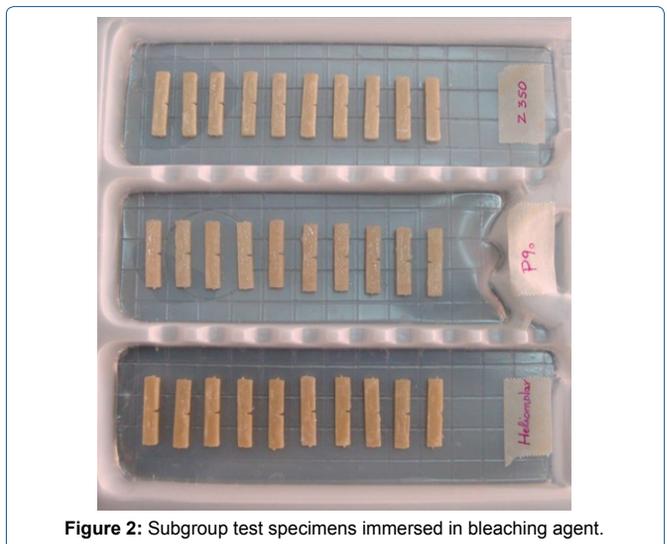


Figure 2: Subgroup test specimens immersed in bleaching agent.

Test specimens were then rinsed and stored in distilled water at 37°C for the remainder of each day during the test. All specimens were subjected to a three-point bending test for two weeks in an Instron Universal Testing Machine (SANTAM, STM-50, Iran) using a crosshead speed of 5 mm/min.

The following formulas were used to calculate the Mode I fracture toughness (K_{Ic}):

$$K_{Ic} = \left(\frac{P_Q}{BW^{\frac{3}{2}}} \right) f(x)$$

$$f(x) = 6x^{\frac{1}{2}} \frac{(1.99 - x(1 - x)(2.15 - 3.93x + 2.7x^2))}{(1 + 2x)(1 - x^{\frac{3}{2}})}$$

K_{Ic} = Mode I fracture toughness; P_Q = fracture load; B = specimen thickness; W = specimen width

The statistical analysis was performed using SPSS 14.0 (SPSS Inc, Chicago II) for Windows analytical software (Microsoft, Inc. Redmond, WA, USA). After calculating the fracture toughness, data were analyzed with the Univariate Analysis of Variance, a One-way ANOVA and the Tukey's HSD ($\alpha=0.05$) tests.

Results

Mean and standard deviation values of K_{Ic} for composite resins before and after bleaching are presented in table 1.

Bleaching	Composite	Mean \pm (Standard Deviation)
Before Bleaching	Filtek Z350	.51575 \pm .066853 α
	Heliomolar	.40500 \pm .040157 β
	Filtek P90	.63010 \pm .054397 α
After Bleaching	Filtek Z350	.52833 \pm .086566 α
	Heliomolar	.46944 \pm .037243 β
	Filtek P90	.58440 \pm .048169 α

Table 1: Mean and standard deviations of K_{Ic} for composite resins tested.

Note: Similar letters following the standard deviation values represent no statically significant difference.

The Univariate Analysis of Variance showed no statistical interaction between two independent variables (type of composite and bleaching application) ($P=0.021>0.05$). Therefore the data was subjected to a one way ANOVA to evaluate of the effect of each variable on the fracture toughness. The ANOVA results showed that 15% carbamide peroxide had no effect on the fracture toughness of nanofilled composite; Filtek Z350™ ($P=0.744>0.05$) or the silorane-based composite; Filtek P90™ ($P=0.62>0.05$), but the fracture toughness of microfilled composite; Heliomolar™ was statistically increased by the bleaching procedure ($P=0.004<0.05$).

A comparison of data among the three test groups revealed that the fracture toughness of Heliomolar™ was significantly less than that of other composites either before or after bleaching. The Tukey test showed that the highest and lowest mean values of K_{Ic} ($P=0.000$, $P=0.002<0.05$) were for Filtek P90™ and Heliomolar™ respectively.

Discussion

This study compared the fracture toughness a silorane-based composite with two dimethacrylate-based composite resins after treatment with 15% carbamide peroxide gel. The different types of composite resins were selected with consideration for types of fillers, filler loading and monomer formulation of the materials to be tested.

Fracture toughness was evaluated using a Universal Testing Machine even though it cannot replicate precise clinical circumstances. However, it is a less technique sensitive procedure capable of producing quantitative results that could be correlated clinically [14].

Cho et al., supported the conclusion of previous studies whose data claimed that materials categorized in the same group do not always have similar physical and mechanical properties. In the present study, even though Filtek Z350™ and Heliomolar™ were dimethacrylate-based, they showed different statistical results in terms of fracture toughness values which was not in agreement with the null hypothesis of the study.

The main difference between the lower mechanical properties of microfilled and other resin composites has been attributed to their lower percentage of filler volume [15,16]. Previous studies found a positive correlation between filler loading and fracture toughness values [15,17]. This might account for the highest and lowest values of K_{Ic} obtained respectively with Filtrek P0™ and Heliomolar™ in the present study either before or after the bleaching procedure.

Bleaching had no effect on the fracture toughness of either Filtrek P90™ or Filtrek Z350™ however, the fracture toughness of Heliomolar™ increased after bleaching. It should be noted that fracture toughness values for Heliomolar™ was the lowest in comparison with the other two composites tested before and after bleaching (Table 1). Nonetheless, Heliomolar™ could work well as a surface layer of anterior restorations because of the high polishability of microfilled composites [16]. Even though Heliomolar™ showed the lowest fracture toughness values, it can significantly improve after bleaching. According to Cho et al., peroxides in the bleaching agent probably acted as an additional initiator of the polymerization of the matrix to increase the average molecular weight of the resin matrix, thus enhancing its mechanical properties.

The present study showed no significant effect of 15% carbamide peroxide gel on the fracture toughness of the nanofilled composite, Filtek Z350™ either before or after bleaching. This finding was consistent with the findings of a previous study done by Cho et al., who showed that nanofilled composite resins with the exception of Filtek Supreme Plus™, were not affected by different concentrations of carbamide peroxide. They other nanofilled composites they tested

included Tetric EvoCeram™, Premise™ and Esthet-X™. They did not include Filtek Z350™ in their study.

Lien et al., compared methacrylate-based with silorane-based composites without manipulating the bleaching variable and showed that the highest fracture toughness values were obtained with silorane. This result was also consistent with the results obtained in the present study with the silorane-based composite subgroup not subjected to bleaching.

Studies have demonstrated that the critical strain energy release rate (G_c) could be increased with the incorporation of a specific filler volume fraction [2]. Favorable particle size and filler volume fraction produces an optimal critical stress intensity factor that might provide another explanation for the constant and identical fracture toughness values in Filtek P90™ and Filtek Z350™ after bleaching.

Further studies are needed required in order to completely understand the various influences that carbamide peroxide has on the fracture toughness and other mechanical properties of silorane-based composite resins.

Conclusion

Within the scope of this study, the microfilled composite (Heliomolar™) was the only composite tested that demonstrated an increase of fracture toughness following the exposure to a 15% carbamide peroxide bleaching gel. The maximum value of K_{Ic} was found with Filtek P90™, while Heliomolar™ showed the least values before and after bleaching with 15% carbamide peroxide gel. So although the Heliomolar composite is microfilled and show increasing the fracture toughness after bleaching but it's still not a good candidate for the surface layer of the restoration of anterior teeth.

Acknowledgement

This study was supported by grant from the Research Council of Mashhad University of Medical Sciences, in Mashhad, Iran.

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