Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2022 Oct 07; 10(D):429-434.
https://doi.org/10.3889/oamjms.2022.10869
eISSN: 1857-9655
Category: *D - Dental Sciences*
Section: *Prosthodontics*

Since 2002

OPEN ACCESS

Evaluation of the Surface Roughness of Resin Composites before and after Applying Different Bleaching Materials

Ahmed Elmarakby[1,2]*, Mohamad Merwah[3], Mohamad Alghamdi[3], Faisal Albaitouni[3], Mohammed Alshreef[3], Fahad Alkahtani[3]

[1]*Department of Restorative Dental Sciences, Vision Colleges for Dentistry and Nursing, Riyadh, Saudi Arabia;* [2]*Department of Operative Dentistry, Faculty of Dental Medicine, Al-Azhar University, Cairo, Egypt;* [3]*General Dentist, Vision College, Riyadh, Saudi Arabia*

Edited by: Aleksandar Iliev
Citation: Elmarakby A, Merwah M, Alghamdi M, Albaitouni F, Alshreef M, Alkahtani F. Evaluation of the Surface Roughness of Resin Composites before and after Applying Different Bleaching Materials. Open Access Maced J Med Sci. 2022 Oct 07; 10(D):429-434. https://doi.org/10.3889/oamjms.2022.10869
Keywords: Nano-filled composite; Surface roughness; Bleaching material
***Correspondence:** Dr. Ahmed Elmarakby, Department of Restorative Dental Sciences, Vision colleges for Dentistry and Nursing, Riyadh, Saudi Arabia; Department, Faculty of Dental Medicine, Al-Azhar University, Cairo, Egypt. E-mail: drahmedmarakby@yahoo.com
Received: 27-Aug-2022
Revised: 26-Sep-2022
Accepted: 27-Oct-2022

Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist

Abstract

BACKGROUND: Bleaching is a conservative treatment and has been shown to be both efficient and safe but the effects of bleaching on teeth and dental materials have been studied in several studies.

AIM: The aim of the present study was to evaluate the surface roughness of resin composites before and after applying different bleaching materials.

MATERIALS AND METHODS: Three types of resin composites were used in this *in vitro* study. Two types of bleaching techniques were used: In office and at home bleach. Sixteen specimens of each resin composite type were fabricated and used in this study. Surface roughness of the samples was measured using a profilometer (Talysurf CLI 1000, Leicester, England). The surface roughness measurements and data were statistically analyzed using the one-way ANOVA and Tukey's tests through SPSS version 21 (SPSS Inc. Chicago, IL, USA). The assessment of surface roughness was done using one-way ANOVA and Tukey's *post hoc* tests. $p < 0.05$ was considered statistically significant.

RESULTS: The assessment of surface roughness by one-way ANOVA and Tukey's *post hoc* tests showed significant differences for composite material types as well as an interaction between these parameters for each tested bleaching gels ($p < 0.05$).

CONCLUSION: The composition of both resin composite and bleaching material plays an important role in initiation and conduction of surface roughness at the outer surface of resin composite restoration.

Introduction

Dental bleaching is currently one of the most common dental esthetic clinical procedures. When properly indicated and administered, this procedure improves patients' self-esteem while having mild effects on their teeth and gingival tissues [1]. Carbamide peroxide (CP) and hydrogen peroxide (HP) are used in the bleaching treatment, which can be done at-home or in-office. The most widely used bleaching agent for at-home bleaching is 15% CP, while HP is the most effective bleaching agent for removing extrinsic and internal stains in the office setting [2]. The oxidation of dentin molecules, which induces color changes, appears to be the mode of action of bleaching agents on tooth structures. The structural integrity of restorative materials can be compromised as a result of this oxidation reaction [3]. The effects of bleaching on teeth and dental materials have been studied in several studies [4], [5], [6], [7], [8]. However, the results are contradictory. Oxidative reactions may have a variety of harmful effects on tooth tissues and restorative dental materials [9]. Surface roughness and hardness are significant clinical indicators of the success of restoration's. On rough restoration surfaces, plaque accumulation, discoloration, gingival irritation, and secondary caries can be seen. Furthermore, materials with a lower surface stiffness are more prone to deformation. The structural properties of the material, such as monomer form, filler type, and percentage, impact the surface roughness and hardness of composite restorations. Roughness and hardness of composite materials are also affected by finishing and polishing of the restorations [10]. Because of the potential for negative physical-mechanical consequences, resin composite restorations are sometimes removed after bleaching in clinical settings [11], [12]. The effects of bleaching of resin-based materials differ depending on the composition of the resin and bleaching gel, as well as the frequency and time of exposure [11]. Microhardness and roughness changes are often used to assess the potential harmful effects of bleaching materials [13], [14]. An increase in superficial roughness is clinically relevant, and regardless of the cause, it leads to the accumulation of food residues and the development of biofilms, which leads to periodontal tissue diseases especially in Class V restorations [15], [16]. Micro-hybrid resins are one of the most widely used resin types. Materials scientists have recently developed nano-filled composites, which have recently been introduced to the dental industry [17], [18]. These nanocomposites were created to provide mechanical strength as well as well-polished surfaces that maintain their integrity over time, including the posterior regions of the mouth [19], [20]. It is crucial to understand how bleaching affects the properties and actions of composite resins so that the best composite resin can be used to restore teeth that have been bleached. This eliminates the need for composite resin repair or replacement due to potential bleaching procedure complications. The aim of this study was to investigate the effects of various bleaching gels on various composite resins by examining roughness changes in the composites surface.

Materials and Methods

Before starting this *in vitro* study, the ethical approval was obtained from the Scientific Research Unit of Al-Farabi College for Dentistry and Nursing. The research proposal was approved by Institutional Review Board (IRB) at Al-Farabi College for Dentistry and Nursing in Riyadh, Saudi Arabia under no. (IRB No.: Alf. dent-2020069).

Selection of composite resin

Three types of resin composites were used in this *in vitro* study. Selection criteria for the composite brands include that they could be of nano fill category with same curing time, same shade, and depth of cure.

1. Ceram.x sphere TEC one universal nano-ceramic restorative (dentsply DeTrey GmbH De-Trey-Str.178467 Konstanz GERMANY)
2. Filtek Z350 XT Universal Restorative (3M ESPE 2510 Conway Avenue St. Paul, MN 55144-1000 USA)
3. Tetric N-Ceram Refill (Ivoclar Vivadent AG FL-9494 Schaan/Liechtenstein

The specifications of each composite resin brand are described in Table 1.

The composite resin specimens were made using a custom-made stainless-steel mold with orifices of 10 mm in diameter and 2 mm in thickness. The mold was positioned on a glass plate and filled with composite resin. A polyester strip was then placed on the composite resin followed by a glass plate to obtain a flat surface. The composite resin was then light cured with the light emitting diode unit Radii-cal (SDI, Australia) for 20 s at 1 mm distance from the surface of the specimen. Surface roughness of composite was measured before starting the application of bleaching material and any measurement values that exceed 0.02 were discarded. Bleaching material was applied on the composite resin surface that was in contact with the polyester strip. Sixteen specimens of each resin composite type were fabricated and stored in distilled water at room temperature for 24 h to complete the polymerization and simulate conditions of the oral cavity environment.

Experimental groups

The 16 specimens of each composite resin were randomly divided into two main groups (n = 8). Each group was subjected to different type of bleaching material: Opalescence 10%PF, Opalescence 40% PF. The composition of each bleaching material is listed in Table 2.

Sample grouping

- Group 1: Represents (Ceram.x sphereTEC one universal nanoceramic restorative) and it referred to as (CS). Then, it subdivided into two subgroups, CS1 (n = 8) and CS2 (n = 8)
- Group 2: Represents (Filtek Z350 XT Universal Restorative) and it referred to as (FZ). Then, it subdivided into two subgroups, FZ1 (n = 8) and FZ2 (n = 8)
- Group 3: Represents (Tetric N-Ceram Refill) and it referred to as (TN). Then, it subdivided into two subgroups, TN1 (n = 8) and TN2 (n = 8).

CS1, FZ1, and TN1 were subjected to Opalescence 40% PF for 3 cycles each one 15 min

Table 1: Specifications and manufacturers of nano fill resin-based composites

Composite resin	Composition	Manufacturer
Ceram.x® sphereTEC™ one universal nano-ceramic restorative	A blend of spherical, pre-polymerized SphereTEC™ fillers (d3,50≈15 μm), non-agglomerated barium glass (d3,50≈0.6 μm) and ytterbium fluoride (d3,50≈0.6 μm). Depending on the shade, the filler load ranges from 77 to 79 weight-% total (59%–61% by volume). Resin matrix contains highly dispersed, methacrylic polysiloxane Nano-particles	DENTSPLY DeTrey GmbH De-Trey-Str. 178467 Konstanz GERMANY
Filtek™ Z350 XT Universal Restorative	Non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler and an aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles). Cluster particle size of 0.6–10 microns. The inorganic filler loading is about 78.5% by weight (63.3% by volume) bis-GMA, UDMA, TEGDMA, PEGDMA and bis-Ema resins	3M ESPE 2510 Conway Avenue St. Paul, MN 55144-1000 USA
Tetric N-Ceram Refill	Consists of dimethacrylates (19–20 weight %). The fillers contain barium glass, ytterbium trifluoride, mixed oxide and copolymers (80–81 weight %). Additives, initiators, stabilizers and pigments are additional contents (< 1 weight %). The total content of inorganic fillers is 55–57 volume %. The particle size of inorganic fillers is between 40 nm and 3000 nm	Ivoclar Vivadent AG FL-9494 Schaan/Liechtenstein

Table 2: Specifications and manufacturers of bleaching materials

Bleaching material	Composition	Manufacturer
Opalescence 40% PF boost (in office)	Hydrogen peroxide 40% Potassium nitrate 3% Sodium fluoride 1.1%	Ultradent product, Inc. USA 505 West Ultradnt drive (10200 South). South Jordan. Utah 84095
Opalescence 10% PF regular (at home bleaching)	Carbamide peroxide 10% Fluoride ion 0.11% Potassium nitrate	Ultradent product, Inc. USA 505 West Ultradnt drive (10200 South). South Jordan. Utah 84095

PF: Potassium Fluoride.

then washed, dried, and stored in distilled water until post-bleaching surface roughness remeasured.

CS2, FZ2, and TN2 were subjected to Opalescence 10%PF for 2 h per day for 14 days and stored in distilled water after every cycle to simulate "at home" bleaching technique. Then, it stored in distilled water until surface roughness remeasured.

Samples were cleaned with a soft toothbrush and distilled water for 1 min to eliminate the bleaching agents from the tooth surfaces. This was done after each cycle of bleaching in Subgroups CS1, FZ1, and TN1, and daily after the completion of bleaching in Subgroups CS2, FZ2, and TN2.

Measurement of surface roughness

Surface roughness of the samples was measured using a profilometer (Talysurf CLI 1000, Leicester, England). The device was calibrated as recommended by the manufacturer. Each sample was subjected to measurements in triplicate, and the mean value was calculated and reported. For the purpose of standardization, surface roughness was measured at the center of samples and at two other points with 2-mm distance from the center.

Statistical analysis

The surface roughness measurements and data were statistically analyzed using the one-way ANOVA and Tukey's tests through SPSS version 21 (SPSS Inc. Chicago, IL, USA). The assessment of surface roughness was done using one-way ANOVA and Tukey's *post hoc* tests. $p < 0.05$ was considered statistically significant.

Results

The assessment of surface roughness by one-way ANOVA and Tukey's tests showed significant differences for composite material type as well as an interaction between these parameters for each tested bleaching gels ($p < 0.05$).

Table 3: Surface roughness measurements (mean values) for Group 1, Subgroup (CS1)

Sample type and no	Samples of Subgroup CS1							
	CS1 1	CS1 2	CS1 3	CS1 4	CS1 5	CS1 6	CS1 7	CS1 8
Before bleach	0.110	0.114	0.130	0.081	0.083	0.105	0.112	0.095
After in office bleach	0.265^{+}	0.382^{++}	0.178	0.127	0.094	0.122	0.188	0.112

$^{++}$Statistically significant. $P < 0.05$ was considered statistically significant.

Results of Group 1: Ceram.x sphereTEC one universal nanoceramic restorative (Dentsply) that has been referred to as (CS) and subdivided into two subgroups, CS1 (n = 8) and CS2 (n = 8) are collected in Tables 3 and 4. Most of the surface measurement values for composite samples of subgroup (CS1: after in office bleach) were in the accepted range except one measurement value (0.382). While most of the surface measurement values for composite samples of subgroup (CS2: after at home bleach) were displayed a degree of roughness after completion of 14 days of at home bleach.

Table 4: Surface roughness measurements (mean values) for Group 1, Subgroup (CS2)

Sample type and no	Samples of Subgroup CS2							
	CS2 1	CS2 2	CS2 3	CS2 4	CS2 5	CS2 6	CS2 7	CS2 8
Before bleach	0.092	0.118	0.087	0.119	0.147	0.102	0.112	0.403
After at home bleach	0.245^{+}	0.157	0.141	0.230^{+}	0.234^{+}	0.248^{+}	0.237^{+}	0.247^{+}

$^{++}$Statistically significant. $P < 0.05$ was considered statistically significant.

Results of Group 2: Filtek Z350 XT Universal Restorative (3M ESPE) that has been referred to as (FZ) and subdivided into two subgroups, FZ1 (n = 8) and FZ2 (n = 8) are collected in Tables 5 and 6. Most of the surface measurement values for composite samples of subgroup (FZ1: after in office bleach) were in the accepted range. While most of the surface measurement values for composite samples of subgroup (FZ2: after at home bleach) were displayed a very high degree of roughness in two samples (0.426 and 0.479) after completion of 14 days of at home bleach.

Table 5: Surface roughness measurements (mean values) for Group 2, Subgroup (FZ1)

Sample type and no	Samples of Subgroup FZ1							
	FZ1 1	FZ1 2	FZ1 3	FZ1 4	FZ1 5	FZ1 6	FZ1 7	FZ1 8
Before bleach	0.101	0.116	0.121	0.071	0.042	0.087	0.166	0.057
After in office bleach	0.209^{+}	0.129	0.175	0.127	0.155	0.169	0.148	0.251^{+}

$^{++}$Statistically significant.

Results of Group 3: Tetric N-Ceram Refill (Ivoclar Vivadent) that has been referred to as (TN) and subdivided into two subgroups, TN1 (n = 8) and TN2 (n = 8) are collected in Tables 7 and 8. Most of the surface measurement values for composite samples of subgroup (TN1: after in office bleach) showed slightly increase than accepted range. While most of the surface measurement values for composite samples of subgroup (TN2: after at home bleach) were displayed a high degree of roughness in two samples (0.301 and 0.385) after completion of 14 days of at home bleach.

Table 6: Surface roughness measurements (mean values) for Group 2, Subgroup (FZ2)

Sample type and no	Samples of Subgroup FZ2							
	FZ2 1	FZ2 2	FZ2 3	FZ2 4	FZ2 5	FZ2 6	FZ2 7	FZ2 8
Before bleach	0.092	0.118	0.087	0.119	0.147	0.102	0.112	0.103
After at home bleach	0.245^{+}	0.157	0.141	0.230^{+}	0.234^{+}	0.248^{+}	0.237^{+}	0.247^{+}

$^{++}$Statistically significant.

Discussion

Bleaching is widely applied in approaches to improve dental esthetics. Due to the chemical nature of this reaction, it is expected that different substrates in the oral environment, such as dental substrates and restorative materials, will respond differently [4], [6], [20]. Different bleaching systems are indicated for at-home or in-office treatments; the active ingredients of these two methods are typically CP and HP, respectively [20], [21], [22]. Due to these differences and the differences in concentration and frequency of use, these two methods can lead to distinct reactions with different restorative materials [3], [4], [23].

Table 7: Surface roughness measurements (mean values) for Group 3, Subgroup (TN1)

Sample type and no	Samples of Subgroup TN1							
	TN1 1	TN1 2	TN1 3	TN1 4	TN1 5	TN1 6	TN1 7	TN1 8
Before bleach	0.140	0.144	0.111	0.107	0.127	0.142	0.083	0.104
After in office bleach	0.280^{+}	0.284^{+}	0.227^{+}	0.179	0.218^{+}	0.174	0.111	0.140

$^{++}$Statistically significant.

This investigation purposed to analyze and evaluate the surface roughness of resin composites before and after applying different bleaching materials. Three types of resin composites were used in this *in vitro* study. Selection criteria for the composite brands include that they could be of nano fill category with same curing time, same shade, and depth of cure. This is done for reduce the variables and for more standardization of factors for more accurate results.

Table 8: Surface roughness measurements (mean values) for Group 3, Subgroup (TN2)

Sample type and no	Samples of Subgroup TN2							
	TN2 1	TN2 2	TN2 3	TN2 4	TN2 5	TN2 6	TN2 7	TN2 8
Before bleach	0.042	0.112	0.173	0.181	0.132	0.141	0.152	0.131
After at home bleach	0.240^{+}	0.204^{+}	0.301^{++}	0.234^{+}	0.201^{+}	0.268^{+}	0.387^{++}	0.373^{++}

$^{++}$Statistically significant.

In the present study, in office bleaching protocol confined to only three sessions (15 min for each session) and these sessions were done at one appointment with no extension to extra weeks or repeated cycles. Results of the present study revealed that in office bleach has a mild effect on the surface roughness of the three types of composite even though the high concentration of HP 40%. This is in agree with study of Wattanapayungkul and Yap [24] about the effect of bleaching materials that commonly indicated as in-office bleaching gels. Results of that study revealed that HP gels affected the surface roughness of nano-filled composites Grandio and Supreme after 3rd and 4th weeks respectively, but enamel and microhybrid resins were not significantly affected ($p > 0.05$). However, they found that when another type and concentration of HP were used, Filtek Z350 was the only material not affected by this bleaching gel over time ($p > 0.05$). Filtek Z250, Grandio and Opallis demonstrated an increase in roughness with an increase in treatment time, but final and initial roughness were not statistically different ($p > 0.05$). Results of the present study revealed that at home bleach caused great changes in surface roughness for all tested composite materials; this effect could be due to the light-sensitive compounds that are found in certain types of bleaching agents but not in the other hydrogen-peroxide or CP bleaching systems. It has been shown in the literature that HP gel can affect surface roughness [4], [20]. This roughening probably occurs due to attack of the organic matrix, causing a softening of the material and leading to gloss loss [23]. Because different compounds are present in both the organic and inorganic fractions of restorative materials, even in products that are similarly categorized, these materials can react differently to the same treatment. This possibility was confirmed in this study. Light can increase the effects of HP treatment on the surface roughness of restorative materials. Regarding the effect of home bleach protocol, results revealed that using the at-home CP gel, lead to different responses of the resin composite materials. The material Ceram.x sphereTEC one universal nanoceramic restorative (Dentsply) was not as affected as Tetric N-Ceram Refill (Ivoclar Vivadent) while the most affected one was Filtek Z350 XT Universal Restorative (3M ESPE), indicating a better performance of some types of nano-filled materials compared to others. This is in agree with another studies that showed greater alterations in surface roughness of composite materials of same category when undergone at home bleach protocol over extended period of time [23], [24]. These data reinforce the statistical analysis that indicated an interaction between factors because the performance of the materials was not consistent with the null hypothesis. It should be highlighted that even at-home bleaching is usually indicated for 2 weeks, it can be extended by the patients due to the lack of supervision of a professional. Rosentritt *et al*. [6] and Gurgan and Yalcin [20] demonstrated that the performance of different composites is strongly influenced by different composition, especially due to monomers. This relationship indicates an interaction between the organic matrix and the bleaching agent. Musange and Ferracane [25] verified the effect of monomers on experimental hybrid resins associated with no silanized nanofilled. In that study, the results also showed a major susceptibility of organic matrixes to bleaching gels. The influence of different bleaching gels depends on the oxidation process that occurs in the organic matrix, which can facilitate water absorption and lead to loss of particles, reducing superficial integrity and micro-hardness [5]. In an extensive review based on original articles that investigated the action of bleaching gels on different material surfaces, Attin *et al*. [3] found that when composite resins are bleached, roughness can be a relevant tool to assess surface changes. Roughness of composite resin seems to be more affected by bleaching than composite shade. However, when saliva is present, adverse consequences are reduced because saliva acts as a protective barrier. Mor *et al*., [12] Steinberg *et al*. [13] and Ulukapi [2] also demonstrated both the ability of saliva to remineralize enamel after bleaching and its fluoride benefits. In the present study, as saliva was not considered, we could assess the potential of bleaching gels without this interference. Bleaching can also alter the optical properties of composite resins, which depend on the composition of materials as well as on the bleaching agent [6], [23]. Results of the present study confirm that the action of the bleaching gel is not due to their low pH because the tested products had basic pH. However, basic environment also can lead to chemical interactions in the oral scenario [24]. In this case, one of the main speculations refers to the hydrolytic action caused by chemical solutions on the organic matrix of resin composites, which is composed of hydrophobic monomers and diluents [26], [27]. It is also noteworthy that specimens were stored in distilled water during the experimental study period, and so, specimens were stored under hydrolytic environment. There is evidence in the literature that demonstrates that water causes changes in the properties of restorative materials. These changes mainly occur at the interface between the filler and organic matrix [26], [27]. Alterations in the molecular structure of the matrix are under evaluation, and studies are being performed to make the matrix more resistant to chemical and mechanical challenges [28]. The inorganic content of resin composites, however, offers resistance to bleaching. Form, amount, and distribution of fillers are all aspects that determine the clinical performance of these restorative materials [28], [29]. Despite advances in the evolution of composites, no material yet exists that is totally resistant to erosion/corrosion that may be resulted after composite resin subjected to any bleaching protocol. Recent studies have reported that the durability of resin based materials can be assured by polishing the composite restorations after bleaching [3], [30,31]. An interesting reaction between bleaching gel and composite resins was reported by Cho *et al*. [32] According to the authors, fracture toughness, which is the measure of a material's ability to resist crack propagation, is considered to be a reliable indicator of the ability of dental materials to resist failure under load. The results of the Cho *et al*. [32] study showed a significant increase in fracture toughness values in the nano-filled composites after bleaching treatments. Cho *et al*. [32] also showed that the initial maximal polymerization of the control groups of other composites resulted in no change in fracture toughness values after bleaching. These reports indicate that the interactions of bleaching gels with resin composites require further investigation. In the present study, we detected differences in roughness between composite resins even though they were from the same category. Reactions to each tested bleaching gel were shown to be material and time-dependent. By the results presented in this study, we cannot affirm that all types of nano-filled composites were more resistant under bleaching protocols than another types of resin composite in the market as it was material and time dependent.

Conclusion

Although bleaching is a conservative treatment and has been shown to be both efficient and safe protocol, but the effects of bleaching on teeth and dental materials have been studied in several studies. Within the limitation of this study, results revealed that composition of both resin composite and bleaching material play an important role in initiation and conduction of surface roughness at the outer surface of resin composite restoration. Despite advances in the evolution of composites, no material yet exists that is totally resistant to erosion/corrosion that may be resulted after composite resin materials subjected to any bleaching protocol.

References

1. Kielbassa AM. Tooth bleaching--increasing patients' dental awareness. Quintessence Int. 2006;37(9):673.
   PMid:17017628
2. Ulukapi H. Effect of different bleaching techniques on enamel surface microhardness. Quintessence Int. 2007;38(4):e201-5.
   PMid:17530052
3. Attin T, Hannig C, Wiegand A, Attin R. Effect of bleaching on restorative materials and restorations--a systematic review. Dent Mater. 2004;20(9):852-61. https://doi.org/10.1016/j.dental.2004.04.002
   PMid:15451241
4. Taher NM. The effect of bleaching agents on the surface hardness of tooth colored restorative materials. J Contemp Dent Pract. 2005;6(2):18-26.
   PMid:15915201
5. Wattanapayungkul P, Yap AU, Chooi KW, Lee MF, Selamat RS, Zhou RD. The effect of home bleaching agents on the surface roughness of tooth-colored restoratives with time. Oper Dent. 2004;29(4):398-403.
   PMid:15279478
6. Rosentritt M, Lang R, Plein T, Behr M, Handel G. Discoloration of restorative materials after bleaching application. Quintessence Int. 2005;36(1):33-9.
   PMid:15709495
7. Arends J, Jongebloed WL, Goldberg M. Schuthof J. Interaction of urea and human enamel. Caries Res. 1984;18(1):17-24. https://doi.org/10.1159/000260742
   PMid:6580950
8. Bailey SJ, Swift EJ Jr. Effects of home bleaching products on composite resins. Quintessence Int. 1992;23(7):489-94.
   PMid:1410250
9. Cehreli ZC, Yazici R, García-Godoy F. Effect of home-use bleaching gels on fluoride releasing restorative materials. Oper Dent. 2003;28(5):605-9.
   PMid:14531608
10. Arcari GM, Baratieri LN, Maia HP, De Freitas SF. Influence of the duration of treatment using a 10% carbamide peroxide bleaching gel on dentin surface microhardness: An *in situ* study. Quintessence Int. 2005;36(1):15-24.
    PMid:15709493

11. Al-Salehi SK, Hatton PV, Miller CA, Mcleod C. Joiner A. The effect of carbamide peroxide treatment on metal ion release from dental amalgam. Dent Mater. 2006;22(10):948-53. https://doi.org/10.1016/j.dental.2005.10.006
PMid:16375959
12. Mor C, Steinbert D, Dogan H, Rotstein I. Bacterial adherence to bleached surfaces of composite resin *in vitro*. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1998;86(5):582-6. https://doi.org/10.1016/s1079-2104(98)90350-x
PMid:9830652
13. Steiberg D, Mor C, Dogan H, Zacks B, Rotstein I. Effect of salivary biofilm on the adherence of oral bacteria to bleached and non-bleached restorative material. Dent Mater. 1999;15(1):14-20. https://doi.org/10.1016/s0109-5641(99)90026-x
PMid:10483391
14. Davis N. A nanotechnology composite. Compend Contin Educ Dent. 2003;24(9):662, 665-7, 669-70.
PMid:14596207
15. Duke ES. Has dentistry moved into the nanotechnology era? Compend Contin Educ Dent. 2003;24(5):380-2.
PMid:12793221
16. Fidelus JD, Wiesel E, Gojny FH, Schulte K, Wagner HD. Thermo-mechanical properties of randomly oriented carbon/epoxy nanocomposites. Compos Part A Appl Sci Manuf. 2005;36(11):1555-61. https://doi.org/10.1016/j.compositesa.2005.02.006
17. Gojny FH, Wichmann MH, Fiedler B, Bauhofer W, Schulte K. Influence of nano-modification on the mechanical and electrical properties of conventional fibre-reinforced composites. Compos Part A Appl Sci Manuf. 2005;36(11):1525-35. https://doi.org/10.1016/j.compositesa.2005.02.007
18. Mitra SB, Wu D, Holmes BN. An application of nanotechnology in advanced dental materials. J Am Dent Assoc. 2003;134(10):1382-90. https://doi.org/10.14219/jada.archive.2003.0054
PMid:14620019
19. Celik C. Arhun N, Yamanel K. Clinical evaluation of resin-based composites in posterior restorations: 12-month results. Eur J Dent. 2010;4(1):57-65. https://doi.org/10.1055/s-0039-1697809
PMid:20046481
20. Gurgan S, Yalcin F. The effect of 2 different bleaching regimens on the surface roughness and hardness of tooth-colored restorative materials. Quintessence Int. 2007;38(2):e83-7.
PMid:17510718
21. De La Pena VA, Cabrita OB. Comparison of the clinical efficacy and safety of carbamide peroxide and hydrogen peroxide in at-home bleaching gels. Quintessence Int. 2006;37(7):551-6.
PMid:16841603
22. Cavalli V, Giannini M, Carvalho RM. Effect of carbamide peroxide bleaching agents on tensile strength of human enamel. Dent Mater. 2004;20(8):733-9. https://doi.org/10.1016/j.dental.2003.10.007
PMid:15302454
23. Yalcin F, Gurgan S. Effect of two different bleaching regimens on the gloss of tooth colored restorative materials. Dent Mater. 2005;21(5):464-8. https://doi.org/10.1016/j.dental.2004.07.011
PMid:15826703
24. Wattanapayungkul P, Yap AU. Effects of in-office bleaching products on surface finish of tooth-colored restorations. Oper Dent. 2003;28(1):15-9.
PMid:12540113
25. Musanje L, Ferracane JL. Effects of resin formulation and nanofiller surface treatment on the properties of experimental hybrid resin composite. Biomaterials. 2004;25(18):4065-71. https://doi.org/10.1016/j.biomaterials.2003.11.003
PMid:15046897
26. Prakki A, Cilli R, Mondelli RF, Kalachandra S, Pereira JC. Influence of pH environment on polymer based dental material properties. J Dent. 2005;33(2):91-8. https://doi.org/10.1016/j.jdent.2004.08.004
PMid:15683889
27. Söderholm KJ, Zigan M, Ragan M, Fischlschweiger W, Bergman M. Hydrolytic degradation of dental composites. J Dent Res. 1984;63(10):1248-54. https://doi.org/10.1177/00220345840630101701
PMid:6592209
28. Wang L, Garcia FC, de Araujo PA, Franco EB, Mondelli RF. Wear resistance of packable resin composites after simulated toothbrushing test. J Esthet Restor Dent. 2004;16(5):303-14; discussion 314-5. https://doi.org/10.1111/j.1708-8240.2004.tb00058.x
PMid:15726799
29. Badra VV, Faraoni JJ, Ramos RP, Palma-Dibb RG. Influence of different beverages on the microhardness and surface roughness of resin composites. Oper Dent. 2005;30(2):213-9.
PMid:15853107
30. Polydorou O, Hellwig E, Auschill TM. The effect of different bleaching agents on the surface texture of restorative materials. Oper Dent. 2006;31(4):473-80. https://doi.org/10.2341/05-75
PMid:16924988
31. Yazici AR, Tuncer D, Antonson S, Onen A, Kilinc E. Effects of delayed finishing/polishing on surface roughness, hardness and gloss of tooth-coloured restorative materials. Eur J Dent. 2010;4(1):50-6. https://doi.org/10.1055/s-0039-1697808
PMid:20046480
32. Cho SD, Bulpakdi P, Matis BA, Platt JA. Effect of bleaching on fracture toughness of resin composites. Oper Dent. 2009;34(6):703-8. https://doi.org/10.2341/08-120-L
PMid:19953780