European Oral Research

Authors' Accepted Manuscript

Effect of surface sealant on the surface roughness of different composites and evaluation of their microhardness

Özge Gürbüz, Alev Özsoy, Benin Dikmen, Meltem Mert Eren, Aylin Çilingir

DOI: 10.26650/eor.20190020

To appear in: *European Oral Research*

Cite this article as: Gurbuz O, Ozsoy A, Dikmen B, Mert-Eren M, Çilingir A. Effect of surface sealant on the surface roughness of different composites and evaluation of their microhardness. Eur Oral Res. Advance online publication. DOI: 10.26650/eor.20190020

This is a PDF file of an unedited manuscript that has been accepted by the **European Oral Research** editor for publication. As a service to our researchers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting galley proof before it is published in its final citable version. Please note that during the production process, typos or errors may be discovered which could affect the content, and all legal disclaimers pertaining to the manuscript.

EFFECT OF SURFACE SEALANT ON THE SURFACE ROUGHNESS OF DIFFERENT COMPOSITES AND EVALUATION OF THEIR MICROHARDNESS*

Özge Gürbüz¹, Alev Özsoy¹, Benin Dikmen¹, Meltem Mert Eren², Aylin Çilingir³

¹ *Department of Restorative Dentistry, Istanbul Medipol University Faculty of Dentistry, Istanbul, Turkey*

² *Department of Restorative Dentistry, Altınbas University Faculty of Dentistry, Istanbul, Turkey*

³ *Department of Restorative Dentistry, Trakya University Faculty of Dentistry, Edirne, Turkey*

Özge Gürbüz

Department of Restorative Dentistry, Istanbul Medipol University Faculty of Dentistry, Istanbul, Turkey

Email: ozgebehram@hotmail.com

Address: TEM Avrupa Otoyolu Göztepe Çıkışı No:1 Bağcılar/Istanbul Turkey

Zip code: 34214

Tel: +902124447044

Alev Özsoy

Department of Restorative Dentistry, Istanbul Medipol University Faculty of Dentistry, Istanbul, Turkey

Email: aoszoy@medipol.edu.tr

Address: Atatürk Bulvarı No:27, 34083 Unkapanı /Fatih/Istanbul/Turkey

Tel: +902124534800

Zip code: 34083

Benin Dikmen

Department of Restorative Dentistry, Istanbul Medipol University Faculty of Dentistry, Istanbul, Turkey

Email: beninsezgin@gmail.com

Address: TEM Avrupa Otoyolu Göztepe Çıkışı No:1 Bağcılar/Istanbul/Turkey

Zip code: 34214

Tel: +902124447044

Meltem Mert Eren

Department of Restorative Dentistry, Kemerburgaz University Faculty of Dentistry, Istanbul, Turkey

Email: meltemmert@hotmail.com

Address: Mahmutbey Dilmenler Caddesi, No:26, Bağcılar/Istanbul/Turkey

Zip code: 34217

Tel: +902126040100

Corresponding author: Aylin Çilingir

Department of Restorative Dentistry, Trakya University Faculty of Dentistry, Edirne, Turkey

Email: aylincinar@hotmail.com

Address: Trakya Üniversitesi Rektörlüğü Balkan Yerleşkesi/Edirne/Turkey

Zip code: 22030

Tel: +902842364550

*Study was presented as a poster at 47th Meeting of the Continental European Division of the International Association for Dental Research (CED-IADR)

ABSTRACT

Purpose: Dental composite resins are commonly used restorative materials for the replacement of hard dental tissues. The aim of this study was to evaluate the effect of a surface sealant on the surface roughness of different composites and compare their microhardness values.

Materials and Methods: Sixty disc-shaped test specimens were prepared and assigned to 3 experimental and 3 groups (n =10 per group). Discs in the group 1 were prepared using Herculite XRV Ultra (Kerr Corporation, Orange, CA, USA); group 2, using Beautifil Bulk Restorative (SHOFU INC., Kyoto, Japan); and group 3, using Filtek Bulk Fill Posterior Restorative (3M-ESPE Dental, Germany). Discs in experimental groups 4, 5, and 6 were prepared using surface sealant (BisCover LV) in addition to the restorative materials used in groups 1, 2, and 3, respectively. The group 1, 2, and 3 discs surface hardness and group 1, 2, 3, 4, 5, 6 surface roughness were measured using the Vickers hardness test and a profilometer, respectively. One-way ANOVA was used to test for differences among the groups.

Results: No significant differences were observed in the microhardness and roughness between the experimental and control groups for each restorative materials. Based on the numerical values Group 3 showed the highest surface hardness and group 4 showed the lowest surface roughness values, respectively.

Conclusion: Using the BisCover LV resin after the polishing step has no significant effect on the surface. The highest hardness values were obtained for the Filtek Bulk Fill Posterior Restorative after the polishing step. Smoothest surfaces were obtained for all experimental groups using the BisCover LV resin after the polishing step, Herculite XRV Ultra showed lower average roughness values than the other materials.

Key words: roughness; microhardness; composite; surface sealant.

Introduction

Dental composite resins are commonly used restorative materials for the replacement of defects in hard dental tissues (1,2). Despite of satisfactory mechanical and esthetic properties, they have some disadvantages too. Polymerization shrinkage causes some problems such as postoperative sensitivity, secondary caries, and marginal leakage. To remove these problems, less than 2-mm-thick layering should be done and it is a time-consuming process. Thus, bulk fill composites have been produced that are claimed to have a low shrinkage stress (3).

Regardless of the cavity class, location and type of the composite material, a smooth surface finish is clinically important because it determines the esthetics and longevity of composite resin restorations (4). Proper finishing of restorations is desirable not only for esthetics but also for good oral health by preventing plaque retention (5). Surface roughness of dental materials can cause microtrauma to the oral tissues and enhance the retention of microorganisms, thereby contributing directly or indirectly to tissue injuries and possible oral diseases (6,7). Therefore, a smooth surface finish is important to maintain good oral health by reducing microorganism retention and plaque accumulation as well as for good esthetic appearance and less recurrent caries and gingival irritation (8,9). An increase in surface roughness can lead to many adverse effects such as susceptibility to staining (10), recurrent caries, and plaque retention (11). Moreover, average surface roughness (Ra) above the 0.2 μm threshold has been reported to increase the colonization and adhesion of bacteria on composite resin surfaces (12). The surface roughness of composite resins is usually dictated by, the size, hardness, and amount of the filler particles, the flexibility of the backing material, and the hardness and grit size of the abrasive (13).

It has been shown that the surface micromorphology of composite resins after finishing and polishing steps can be influenced by the size, hardness and amount of the filler particles (14). During the polishing

of hybrid composites, the harder filler particles are left protruding from the surface, whereas the softer resin matrix is preferentially removed. Therefore, the harder filler particles should be packed close together to protect the soft resin matrix from abrasives (15). The combination of reduced particle dimensions and wider size distribution allows the higher levels of filler loading, resulting in reduced polymerization shrinkage and improved mechanical properties (16). To achieve an effective finishing system for composite resins, the abrasive particles should be relatively harder than the filler materials to prevent the preferential removal of the soft resin matrix during polishing, leaving the harder filler particles protruding from the surface (13). According to earlier work, larger filler particles have resulted in greater Ra values (17,18). The composite resins with higher concentrations of small-sized filler particles have become popular in recent years due to the difficulties in producing smooth surfaces similar to the enamel surface using the composite resins that have larger filler particles. Typically, increased amounts of filler particles result in smoother surfaces because of the decreased particle size and better particle distribution within the resin matrix (13).

Surface sealants have been developed to preserve or improve the mechanical properties of direct restorative materials. Thus, application of the surface sealants after the polishing step has been recommended to increase the longevity of restorations (21,22). Liquid polishing materials are low-viscosity, light-polymerized resin formulations with a low amount of filler particles that provide a smooth, sealed surface for interim and composite resin restorations (14,23,24). Surface penetrating sealants (SPS) are unfilled low-viscosity resins polymerized onto the composite surfaces to promote the filling of structural microdefects and microfissures by capillary action (25) for maintaining the surface smoothness, improving the wear resistance (25,26) and marginal sealing (27) of the restoration. Since various surface defects such as microcracks and irregularities are formed due to the removal of some of the surface particles during finishing, application of the liquid resin to the finished material surface has been recommended to repair the structural microdefects and improve the abrasion resistance of posterior composite resins (28,29).

However, the effectiveness of sealants in improving the smoothness of composite surfaces is still controversial. Although some authors have suggested that sealants might be desirable to improve the surface finish of composites (21,30), others have reported no significant reduction in the surface roughness of composites after the simulated abrasion test (31) and also in clinical evaluations after one and five years (25,32).

Substantial surface hardness of the restoration is one of the main requirements in high stress-bearing areas such as posterior restorations (33). Materials which have reduced surface hardness are more susceptible to deformation (34). Microhardness can be influenced by monomer type, filler type, morphology, volume and weight (34-36). Moreover, finishing and polishing of the restoration can affect the hardness of the composite materials (34).

There are some studies that compare microhardness of different bulk fill composite materials and declare various results (37-41). It is stated that bulk fill composites with low filler content showed lower microhardness than with high filler contents (3,42,43). Alshali et al. reported that bulk fill materials showed comparable hardness to conventional composites despite their increased thickness (44). Despite of various results about the microhardness of various bulk fill composites, there has been no previously reported study that compare the microhardness of bulk fill composites chosen in our study each other (44).

The aim of this study was to evaluate the effect of the BisCover LV resin sealant on the roughness of different composites and compare their microhardness values. Based on this information, the following null hypotheses were tested: (1) surface sealant has a positive effect on the roughness of composite materials (2) there were no significant difference between the microhardness of the composite materials used in this study.

Materials and Methods

Table 1. Groups and materials used

n=10	group 1	group 2	group 3	group 4	group 5	group 6
composite restoration	Herculite XRV Ultra	Beautifil Bulk Restorative	3M Filtek BulkFill	Herculite XRV Ultra	Beautifil Bulk Restorative	3M Filtek BulkFill
BisCover application after restoration	-	-	-	+	+	+

Table 2. Characteristics of materials tested

	Composition	Manufacturer	Classification	Filler	Filler loading
Herculite XRV Ultra	Ethoxylated Bis-GMA, TEGDMA, BisEMA	Kerr, Orange, CA, USA	Nano-hybrid composite	SiO ₂ (20–50nm), Barium silicate glass (0,4m), Prepolymerized filler with barium silicate glass and silica (30–50m)	71 wt% /54 vol%
Beautifil Bulk Restorative	Bis-GMA, UDMA, Bis-MPEPP, TEGDMA	Shofu Inc, Kyoto, Japan		Surface modified prereacted glass (S-PRG) filler based on fluoroboroaluminosilicate glass, polymerization initiator	87 wt% /74.5 vol%
3M Filtek BulkFill	Bis-GMA, UDMA, Bis-EMA(6), procrylat resins	3M ESPE, St. Paul, MN, USA	Bulk-fill paste composite with glass microfibres	Zirconia/Silica, ytt erbium trifluoride	76.5 wt%/58.5 vol%
Biscover LV	Dipentaerythritol pentaacrylate esters and Etanol	Bisco Inc, Schaumburg, IL, USA	Low-viscosity liquid polish		

Specimen preparation: Ten disc-shaped specimens with 3 mm diameter and 10 mm thickness were prepared in a Teflon mold for each study group (Figure 1) (11). Total sixty disc-shaped specimens were prepared for the surface property tests and assigned into 6 groups. Different study groups and materials used in this study are outlined in Table 1, and the properties and type of the used materials are presented in Table 2. The composite resins were poured in a Teflon mold covered with a polyester strip and a glass slide (1-2 mm thick) was then placed over the polyester strip to flatten the surfaces according to the composite manufacturer's recommendation. The restorative materials were light-cured (Optilux Demetron, VLC 403, Danbury, CT, USA, 500 mW/cm²) followed by 10 seconds polishing using medium grade polishing discs (OptiDisc, Kerr Hawe, Karlsruhe, Germany). A new polishing disc was used for each specimen and then discarded after each use. Medium polishing disc was used because it provides roughness similar to a yellow banded bur. Specimens in experimental groups 4, 5, and 6 were etched with 32% phosphoric acid (Uni-Etch, Bisco Inc., Schaumburg, IL, USA) for 15 s. Then, the etched specimens were rinsed with water and air dried before directly applying the BisCover LV resin (dipentaerythritol pentaacrylate in ethanol) (BisCover, Bisco Inc., Schaumburg, IL, USA) using a syringe and an applicator tip. After a 15-s wait for ethanol vaporization, specimens were light polymerized for 30 s using an Ultralux halogen light unit as per the manufacturer's instruction. The light curing unit tip was positioned perpendicular to the specimens' surfaces, and the distance between the tip and the specimen was standardised using a glass microscope slide (1 mm in thickness). All samples were stored in distilled water at 37 °C for 24 hours. This research was conducted at Istanbul Medipol University and Istanbul University Laboratory.

Figure 1. Teflon mold composites prepared in

Microhardness Measurements

Surface hardness of different composite resins was measured using the Vicker's hardness test because of its ease-of-use and reliability of the measurements (45). The microhardness values for the samples in groups 1, 2, and 3 were obtained using an Innovatest Nexus 4503 hardness testing machine (Innovatest Europe, Maastricht, The Netherlands) for loads of 2.5 – 10 kgf (24.51 – 98.07 N) (Figure 2). The surface hardness measurements were performed using a microscope at 200x magnification under a load of 300 g for 15 s. The applied load and the hold time were kept constant for all samples throughout the study. The measurement was carried out three times in each sample at random locations and a mean value was calculated.

Figure 2. Hardness testing machine

Surface Roughness Measurements

Surface roughness of different composite resins was determined using the roughness average (Ra) parameter, which represents the arithmetic average of absolute values of the profile height deviations from the mean line recorded within the evaluation length (46). A profilometer (Taylor Hobson Surtronic 25, UK) was used for measuring the Ra values of groups 1, 2, 3, 4, 5, 6. For surface roughness test, readings were taken at three random locations on each surface and the average roughness value (Ra, μm) was obtained by using the arithmetic mean of these three readings.

Statistical analysis

Statistical data analysis was performed using the statistical package for the social sciences. Descriptive statistics for continuous variables were calculated and reported in a mean $\pm$ standard deviation format. To detect differences among Ra and microhardness values for different groups, a one-way analysis of variance (ANOVA) method was used at the 0.05 level of significance.

Results

Mean microhardness and roughness values for different groups are presented in Table 3 and Table 4. There were no significant differences in microhardness and roughness values between the experimental and control groups for each restorative material. Based on the test results, group 3 showed the highest surface hardness and group 4 showed the lowest surface roughness values. Figures 3 and 4 show the general homogeneity in microhardness and surface roughness values among different groups.

Table 3. Mean microhardness values and differences within groups (no significant differences $p > .05$)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower bound	Upper Bound
1	10	61,1370	10,10009	3,19393	53,9118	68,3622
2	10	58,4860	8,32322	2,63203	52,5319	64,4401
3	10	66,6520	6,43766	2,03577	62,0468	71,2572
Total	30	62,0917	8,83112	1,61233	58,7941	65,3893

Table 4. Mean Roughness (Ra) values and differences within groups (no significant differences $p > .05$)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
1	10	0,8540	0,23153	0,07322	0,6884	1,0196
2	10	0,7730	0,24459	0,07735	0,5980	0,9480
3	10	0,7190	0,14579	0,04610	0,6147	0,8233
4	10	0,7030	0,25347	0,08015	0,5217	0,8843
5	10	0,7110	0,25723	0,08134	0,5270	0,8950
6	10	0,8720	0,19921	0,06300	0,7295	1,0145
Total	60	0,7720	0,22636	0,02922	0,7135	0,8305

Figure 3. Surface Microhardness Statistics Descriptives Homogeneity

Figure 4. Surface Roughness (Ra) Statistics Descriptives Homogeneity

Discussion

The clinical significance of surface roughness and hardness is related to the esthetic restorations (discoloration and wear), the medical consequences of periodontal disease, and the development of secondary caries due to increased plaque accumulation. Wear and microleakage are the main limitations of the composite resins in mainly posterior restorations (47). Several research groups have studied the surface characteristics of different restorative materials (11,31,48-50) using contact profilometers, which detect surface irregularities using a stylus moving vertically across the surface. In addition, clinical studies have shown that the rough surfaces can promote plaque formation and reduce the efficiency of teeth cleaning procedures (51). Bollen et al. reported that a Ra of 0.2 μm or more could result in accumulation of bacterial plaque, thereby promoting the periodontal diseases and carious lesions (12,21). However, results from this study showed that the mean Ra and microhardness values obtained at the baseline for the experimental and control groups did not differ statistically from each other.

Effective surface sealants should have good surface wettability, a low contact angle, a low viscosity, and good penetration capability. Microgaps may occur between tooth/restoration interface depending on the polymerization shrinkage during restoring the tooth with resin composites. Surface sealants minimize the wear rates of the resins by filling the microdefects on the restorations (47). Therefore, the presence of low molecular weight monomers was found to be essential in dental sealants (48). It was assumed that a surface sealant containing Bis-GMA combined with low molecular weight monomers (TEGDMA and THFMA) would control its desirable characteristics such as viscosity and surface wettability (25). Also fillers were added to some sealants to increase their mechanical properties (47).

The wear resistance of composite resins can be enhanced with a surface sealant, as long as it is annually applied. In an in vivo study, the researchers found that the wear values of the sealed restorations after one year were approximately half of those found in the non-sealed restorations (25). In addition, these low viscosity resins can increase the wear resistance of the tooth/restoration interface in luting indirect restorations (26).

Surface sealant application may not be necessary due to nano-fill composites have good wear resistance and good polishability (47). Nanohybrid composite resin showed the lowest Ra values compared with those of the hybrid and microhybrid composite resins (30).

Although relatively smoother surfaces were obtained with the polyester strips, the use of a glazing material after the polishing step resulted in significantly lower Ra values compared to that obtained with the use of polyester strips alone. The glazing material appeared to fill the structural microdefects, thereby providing a more uniform and smooth surface (30). However, some initial investigations demonstrated the degradation of the glazing materials over time, in spite of their resistance to toothbrushing and staining (31,52,47). Therefore, the limitations of this in vitro study have to be developed and improved in terms of aging.

The effectiveness of sealants in improving the smoothness of composite surfaces is still controversial. Although some authors have suggested that sealants might improve the surface finish (30), others have reported no significant reduction in the surface roughness of composites after the simulated toothbrushing abrasion test and also in clinical evaluations after one and five years (25). The complex structure of a surface cannot be fully characterized by the use of only surface roughness measurements (15).

However group 4 (Herculite XRV Ultra with sealant application) has the lowest roughness values, there weren't statistically significant differences between the groups tested in this study. The lowest roughness might be due to the fact that Herculite XRV Ultra was a nanocomposite and the surface was sealed after finishing and polishing procedure.

According to Shintani and others, there were no noticeable differences in plaque accumulation among the surfaces polished using different methods, which resulted in Ra values within the range of 0.7-1 μm (53). Chung reported that restorations with less than 1 μm surface roughness appeared to be optically smooth (14).

The inherent surface roughness of composite resins should be equal to or lower than the surface roughness of enamel-to-enamel occlusal contact areas ($R_a = 0.64 \mu\text{m}$). When comparing the roughness values of optimally polished surfaces, mostly the surface roughness values produced by pressing the restorative materials against transparent matrices such as Mylar strips are used (54). Thus, very smooth polished surfaces representative of the clinical situation can be obtained using clear matrices. Although the surface obtained with Mylar strip is perfectly smooth, it is rich in resin organic binder (54). Therefore a medium grade polishing disc was used to mimic the clinic conditions before applying the surface sealant in this study.

It has been reported that a noticeable decrease in mean surface roughness could be achieved within first five seconds of polishing for practically all restorative materials, but a further decrease of the same magnitude could not be obtained with longer polishing times or the application of additional components (55). Thus, one-step polishing systems offer time saving benefit along with reduced roughness when polishing the composite restorations. Based on this fact one-step surface sealant was used when evaluating the resin surfaces in this study.

The first null hypothesis tested was partially rejected because the surface sealant material showed a positive effect on the surface roughness of composite resins, but there were no significant differences in the roughness values between the experimental and control groups for each restorative material. Different results may be obtained with different polishing techniques and composite resin materials.

Several factors related to the composite resin compositions were shown to affect the surface hardness of the composite restorative materials (55). It was observed that the mass fraction (56,57), size, and distribution of filler particles have significant effects on certain physical and mechanical properties, including surface hardness of the composite resins (58,59). Moreover, other parameters such as filler particle shape and density, monomer type and ratio, degree of crosslinking, and photoinitiators have also shown significant influence on the surface hardness of restorative materials (56,60).

A microhardness test gives information as to the mechanical properties of the material. A positive correlation has been determined between the hardness and inorganic filler content of composites. Increased organic filler levels result in increased hardness values (11).

In a study on filler particle size effect, significant high differences were noticed in the VHN (Vickers hardness number) mean values among bulk-fill and incrementally-fill composite resins, either for top or bottom surfaces. The highest VHN value was obtained for the incremental-fill nanohybrid composite (Grandio) compared to that of the two bulk-fill microhybrid composites (X-tra fil and QuiXfil) (61). According to Moszner et al. (16) and Thome et al. (62), the microhybrid composite resins exhibited higher microhardness values than that of the nanohybrid composite resin.

The second null hypothesis that, there were no significant differences between the microhardness of the composite materials used was accepted. Despite there were no significant differences between the groups tested, group 3 had the highest microhardness values. This could be attributed to the filler particles of (glass microfibres, zirconia, silica and ytterbium trifluoride) the Filtek Bulk-fill. Also it can be speculated that bulk-fill resin composites allow more light to penetrate deep inside and which can result in more polymerized monomers. It's in agreement with a previous study (63).

Therefore, further investigation is necessary to evaluate the surface roughness and microhardness values for different composite resins and polishing techniques.

Conclusion

In this study, the highest hardness values were obtained using Filtek Bulk Fill Posterior Restorative (silane treated ceramic, 3M-ESPE, Germany) after the polishing step. The smoothest surfaces were obtained using a surface sealant after the polishing step, Herculite XRV Ultra showed lower R_a values compared with those of the other restorative materials. No significant differences were found in the surface roughness of selected composite resins sealed with BisCover LV.

Similarly, the microhardness values showed no significant differences among different composite resin materials. Hardness value obtained for group 3 is higher but not significantly different compared to that of the groups 1 and 2. As a result, the glazing material showed a negligible effect on the surface roughness values of different polished composite resins.

The current generation of composite resins focused on the filler particle size (nano-fill and bulk-fill) have improved the surface properties such as hardness and roughness of restorative materials. Therefore, the use of sealants to improve the smoothness and hardness of these composite restorations is questionable. Longitudinal clinical trials are necessary to validate this hypothesis and provide further insights into the design of composite resins for clinical use.

Acknowledgements: We acknowledge the Istanbul Medipol University Faculty of Dentistry, Department of Restorative Dentistry and the Istanbul University Faculty of Dentistry, Department of Restorative Dentistry for providing the research facilities.

References

1. Velasco Ortega E, JosA, CameánAM, Pato-MoureloJ, Segura-Egea JJ. In vitro evaluation of cytotoxicity and genotoxicity of a commercial titanium alloy for dental implantology. *Mutat Res* 2010;702:17–23.
2. Angelieria F, Marcondesb JPC, de Almeida DC, Salvadori DMF, Ribeiro DA. Genotoxicity of corrosion eluates obtained from orthodontic brackets in vitro. *Am J Orthod Dentofac Orthop* 2011;139:504–509.
3. Son SA, Park JK, Seo DG, Ko CC, Kwon YH. How light attenuation and filler content affect the microhardness and polymerization shrinkage and translucency of bulk-fill composites? *Clin Oral Investig*. 2017; 21(2): 559–565.
4. Yap AU, Yap SH, Teo CK, Ng JJ. Finishing/polishing of composite and compomer restoratives: effectiveness of one-step systems. *Oper Dent* 2004;29:275–279.
5. Yap AU, Tan S, Teh TY. The effect of polishing systems on microleakage of tooth coloured restoratives: part 1. Conventional and resin-modified glass-ionomer cements. *J Oral Rehabil* 2000;27:117–123.
6. Abuzar MA, Bellur S, Duong N, Kim BB, Lu P, Palfreyman N, et al. Evaluating surface roughness of a polyamide denture base material in comparison with poly (methyl methacrylate). *J Oral Sci* 2010;52:577–581.
7. Chatzivasileiou K, Emmanouil I, Kotsiomi E, Pissiotis A. Polishing of denture base acrylic resin with chairside polishing kits: an SEM and surface roughness study. *Int J Prosthodont* 2013;26:79–81.
8. Sarikaya I, Güler AU. Effects of different polishing techniques on the surface roughness of dental porcelains. *J Appl Oral Sci* 2010;18:10–16.
9. Giacomelli L, Derchi G, Frustaci A, Bruno O, Covani U, Barone A, et al. Surface roughness of commercial composites after different polishing protocols: an analysis with atomic force microscopy. *Open Dent J* 2010;4:191–194.
10. Lu H, Roeder LB, Lei L, Powers JM. Effect of surface roughness on stain resistance of dental resin composites. *J Esthet Rest Dent* 2005;17:102–108.
11. Korkmaz Y, Ozel E, Attar N, Aksoy G. The influence of one-step polishing systems on the surface roughness and microhardness of nanocomposites. *Oper Dent* 2008;33:44–50.
12. Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention. A review of the literature. *Dent Mat* 1997;13:258–269.
13. Reis AF, Giannini M, Lovadino JR, dos Santos Dias CT. The effect of six polishing systems on the surface roughness of two packable resin-based composites. *Am J Dent* 2002;15:193–197.
14. Chung K. Effects of finishing and polishing procedures on the surface texture of resin composites. *Dent Mater* 1994;5:325–330.
15. Ergucu Z, Turkun LS. Surface roughness of novel resin composites polished with one-step systems. *Oper Dent* 2007;32-2:185–192.
16. Moszner N, Salz U. New developments of polymeric dental composites. *Prog Polym Sci* 2001;26:535–176.

17. Ozgunaltay G, Yazıcı AR, Gorucu J. Effect of finishing and polishing procedures on the surface roughness of new tooth-coloured restoratives. *J Oral Rehabil* 2003;30:218-124.
18. Paravina RD, Roeder L, Lu H, Vogel K, Powers JM. Effect of finishing and polishing procedures on surface roughness, gloss and color of resin-based composites. *Am J Dent* 2004;17:262-266.
19. Bayne SC, Heymann HO, Swift EJ Jr. Update on dental composite restorations. *J Am Dent Assoc* 1994;125:687-701.
20. Lee YK, Powers JM. Combined effects of staining substances on resin composites before and after surface sealant application. *J Mater Sci Mater Med* 2007;18:685-691.
21. dos Santos PH, Consani S, Sobrinho LC, Sinhoreti MA. Effect of surface penetrating sealant on roughness of posterior composite resins. *Am J of Dent* 2003;16:197-201.
22. dos Santos PH, Pavan S, Consani S, Sobrinho LC, Sinhoreti MA, Filho JN. In vitro evaluation of surface roughness of 4 resin composites after the toothbrushing process and methods to recover superficial smoothness. *Quintessence Int* 2007;38:247-253.
23. Güler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stainability of resin composite provisional restorative materials. *J Prosthet Dent* 2005;2:118-124.
24. Sen D, Goller G, Issever H. The effect of two polishing pastes on the surface roughness of bis-acryl composite and methacrylate-based resins. *J Prosthet Dent* 2002;5:527-532.
25. Dickinson GL, Leinfelder KF, Mazer RB, Russell CM. Effect of surface penetrating sealant on wear rate of posterior composite resins. *J Am Dent Assoc* 1990;121:251–255.
26. Prakki A, Ribeiro IWJ, Cilli R, Mondelli RFL. Assessing the tooth-restoration interface wear resistance of two cementation techniques: effect of a surface sealant. *Oper Dent* 2005;30:739–746.
27. Ramos RP, Chimello DT, Chinelatti MA, Dibb RG, Mondelli J. Effect of three surface sealants on marginal sealing of class V composite resin restorations. *Oper Dent* 2000;25:448–453.
28. Barghi N, Alexander C. A new surface sealant for polishing composite resin restorations. *Compend Contin Educ Dent* 2003;24:30-33.
29. Roeder LB, Tate WH, Powers JM. Effect of finishing and polishing procedures on the surface roughness of packable composites. *Oper Dent* 2000;25:534-543.
30. Sarac D, Sarac YS, Kulunk S, Ural C, Kulunk T. The effect of polishing techniques on the surface roughness and color change of composite resins. *J Prosthet Dent* 2006;96:33–40.
31. Takeuchi CYG, Orbegoso Flores VH, Palma Dibb RG, Panzeri H, Lara EHG, Dinelli W. Assessing the surface roughness of a posterior resin composite: effect of surface sealing. *Oper Dent* 2003;28:283–288.
32. Dickinson GL, Leinfelder KF. Assessing the long-term effect of a surface penetrating sealant. *J Am Dent Assoc* 1993;124:68–72.
33. Moraes LGP, Rocha RSF, Menrgazzo LM, Araujo EB, Yukimitu K, Moraes JCS. Infrared spectroscopy: a tool for determination of the degree of conversion in dental composites. *J Appl Oral Sci* 2008;16:145-149.
34. Yıkılğan I, Kamak H, Akgul S, Ozcan S, Bala O. Effects of three different bleaching agents on microhardness and roughness of composite sample surfaces finished with different polishing techniques. *J Clin Exp Dent* 2017; 9: e460-5
35. Shafiei F, Doustfatemeh S. Effect of a Combined Bleaching Regimen on the Microhardness of a Sealed Methacrylate-based and a Silorane-based Composite. *J Dent Shiraz Univ Med Sci*, 2013; 14: 111-117.
36. Tekce N, Pala K, Tuncer S, Demirci M. The effect of surface sealant application and accelerated aging on posterior restorative surfaces: An SEM and AFM study. *Dent Mater J*, 2017; 36: 182-189.
37. Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin-composites. *Dent Mater* 2014; 30(2): 149-54.
38. El-Damanhoury H, Platt J. Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. *Oper Dent* 2014; 39(4): 374-82.
39. Czasch P, Ilie N. In vitro comparison of mechanical properties and degree of cure of bulk fill composites. *Clin Oral Investig*. 2013; 17(1): 227-35.
40. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. *J Dent* 2014; 42(8): 993-1000.

41. Do T, Church B, Verissimo C, Hackmyer SP, Tantbirojn D, Simon JF, Versluis A. Cuspal flexure, depth-of-cure, and bond integrity of bulk-fill composites. *Pediatr Dent* 2014; 36(7): 468-73.
42. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LE, Martin AA, Ambrosano G, Giannini M. Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. *Dent Mater* 2015; 31(12): 1542-51.
43. Garoushi S, Vallittu P, Shinya A, Lassila L. Influence of increment thickness on light transmission, degree of conversion and micro hardness of bulk fill composites. *Odontology*. 2016; 104(3): 291-7
44. Alshali RZ, Salim NA, Satterthwaite JD, Silikas N. Post-irradiation hardness development, chemical softening, and thermal stability of bulk-fill and conventional resin-composites. *J Dent* 2015; 43(2): 209-18.
45. Galvao MR, Caldas SG, Bagnato VS, Rastelli AN, Andrade MF. Evaluation of degree of conversion and hardness of dental composites photoactivated with different light guide tips. *Eur J Dent* 2013;7:86-93.
46. Whitehead, SA, Shearer, AC, Watts, DC, Wilson, NH, 1995. Comparison of methods for measuring surface roughness of ceramic. *J Oral Rehabil* 1995;22:421-427.
47. Lopes MB, Saquy PC, Moura SK, Wang L, Graciano FMO, Correr Sobrinho L, Gonim junior A. Effect of Different Surface Penetrating Sealants on the Roughness of a Nanofiller Composite Resin. *Braz Dent J* (2012) 23(6): 692-697
48. D'Alpino PH, Pereira JC, Rueggeberg FA, Svizero NR, Miyake K, Pashley DH. Efficacy of composite surface sealers in sealing cavosurface marginal gaps. *J Dent* 2006;34:252-259
49. Yap AUJ, WU SS, Chelvan S, Tan ESF. Effect of hygiene maintenance procedures on surface roughness of composite restoratives. *Oper Dent* 2005;30:99-104.
50. Kawai K, Leinfelder KF. Effect of surface-penetrating sealant on composite wear. *Dent Mater* 1993;9:108-113.
51. Van Dijken JW, Sjöström S, Wing K. The effect of different types of composite resin fillings on marginal gingiva. *J Clin Periodontol* 1987;14:185-189.
52. Doray PA, Eldiwany MS, Powers JM. Effect of resin surface sealers on improvement of stain resistance for a composite provisional material. *J Esthet Restor Dent* 2003;15:244-250.
53. Shintani H, Satou J, Satou N, Hayashihara H, Inoue T. Effect of various finishing methods on staining and accumulation of *Streptococcus mutans* HS-6 on composite resin. *Dent Mater* 1985;1:225-227.
54. Willems G, Lambrechts P, Braem M, Vuylsteke-Wauters M, Vanherle G. The surface roughness of enamel-to-enamel contact areas compared with the intrinsic roughness of dental resin composites. *J Dent Res* 1991;70:1299-1305.
55. Heintze SD, Forjanic M, Rousson V. Surface roughness and gloss of dental materials as a function of force and polishing time in vitro. *Dent Mater* 2006;22:146-165.
56. Leprince JG, Palin WM, Mullier T, Devaux J, Vreven J, Leloup G. Investigating filler morphology and mechanical properties of new low-shrinkage resin composite types. *J Oral Rehabil* 2010;37:364-376.
57. Knobloch LA, Kerby RE, Clelland N, Lee j. Hardness and degree of conversion of posterior packable composites. *Oper Dent* 2004;9:642-649.
58. Bucutas S, Ilie N. Light transmittance and micro-mechanical properties of bulk-fill vs conventional resin composites. *Clin Oral Invest* 2014;18:1991-2000.
59. Hahnel S, Dowling AH, El-Safty S, Fleming GJP. The influence of monomeric resin and filler characteristics on the performance of experimental resin-based composites (RBCs) derived from a commercial formulation. *Dent Mater* 2012;28:416-423.
60. Mobarak E, Elsayed I, Ibrahim M, El-Badrawy W. Effect of LED light-curing on the relative hardness of tooth-colored restorative materials. *Oper Dent* 2009;34:65-71.
61. Abed YA, Sabry HA. Alrobeigy. Degree of conversion and surface hardness of bulk-fill composite versus incremental-fill composite. *Tanta Dental Journal* 2015;12:71-80.
62. Thome T, Steagall JrW, Tachibana, et al. Influence of distance of curing light source and composite shade on hardness of two composites. *J Appl Oral Sci* 2007;15: 486-941.
63. Kim EH, Jung KH, Son SA, Hur B, Kwon YH, Park JK. Effect of resin thickness on the microhardness and optical properties of bulk-fill resin composites. *Restor Dent Endod*. 2015 May;40(2):128-35.