



In-vitro Comparison of the Impact of Four Types of Resin Composite on the Repaired Bond Strength and Surface Roughness After Sandblasting

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ABSTRACT

Background and Aim: One of the major problems with resin composite restorations is the weakness of bonding between the new and aged composites. Since appropriate micromechanical retention is necessary for the repair of aged resin composite restorations, the level of surface roughness after sandblasting can be influential in this regard. Considering the diverse composition of available resin composites in the market, the present study was performed to compare the impact of four resin composite types: Micro-hybrid (Z250), Nano-fill (Z350XT), Nano-hybrid (Z250XT) and Silorane-base (p90) on the repaired bond strength and surface roughness after sandblasting.

Methods and Materials: In this in-vitro experimental study, 44 resin composite discs with the diameter of 6mm and height of 2mm were divided to 4 groups of Micro-hybrid, Nano-fill, Nano-hybrid and Silorane-base and from 11 samples of each resin composite type, one sample was evaluated for surface roughness level before and after sandblasting with Atomic Force Microscope (AFM) and 10 samples were tested for shear bond strength in universal testing machine.

Results: The findings indicated that Micro-hybrid resin composite had the highest shear bond strength (37.8±6.4 MPa) followed respectively by Nano-fill (30 ±3.8 MPa), Silorane-base (17.9±4 MPa) and Nano-hybrid composites (7.6±1.9 MPa). The differences between all groups were significant (p <0.000).

Before sandblasting, Nano-hybrid type had the highest level of surface roughness (505 ±154nm) and the lowest value was related to Micro-hybrid resin composite (94±35nm) (p<0.000). After sandblasting, Nano-fill (1997±288nm), Silorane-base, Micro-hybrid and Nano-hybrid composites (1284 ± 645nm) showed the highest increase in surface roughness, respectively (p<0.4).

Conclusion: In the present study, sandblasting caused a significant increase in the surface roughness of the four studied resin composite types. Despite the lowest surface roughness of Micro-hybrid type, it showed the highest bond strength amongst other composites after sandblasting.

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Introduction:

One of the major problems with resin composite restorations is the weakness of bonding between the new and aged composites. Since appropriate micromechanical retention is necessary for the repair of aged resin composite restorations and as the chemical bond alone cannot provide adequate retention, the amount of surface roughness of resin composite can influence the bond strength between new and aged resin composite restorations.⁽¹⁾ Nowadays, resin composites are widely being used.^(1, 2) Physical and mechanical properties of resin composites have been improved greatly during the past 10 to 20 years.

Nevertheless, oral enzymes can destruct their matrix.⁽³⁾ Therefore, eventually the old restoration needs to be repaired or replaced and on the other hand, since the replacement of these restorations is time consuming and leads to loss of some dental structure, repair of these restorations is preferred over their replacement.⁽⁴⁻⁷⁾ The important factor is the bond strength between the new and aged resin composites.⁽⁸⁾

Usually, bonding between two resin composite layers is possible in the presence of an oxygen inhibited non-polymerized surface, and since old restorations lack this surface, various techniques have been presented for surface treatment.^(9, 10) The importance of surface treatment is in the increase of micromechanical bond between the new and old resin composite restorations.^(1, 7, 8)

Numerous studies have been performed to introduce the best surface treatment technique. The evaluated techniques include the use of diamond burs, sandblasting with 50 μ aluminum oxide particles, sandblasting with aluminum oxide particles covered with silica (cojet) and etching with hydrofluoric acid.^(1-4, 9)

In multiple studies, sandblasting has been introduced as the best surface treatment method for the aged resin composite but considering the different composition of resin composites and differences in the size and type of filler particles such as (Macro-filled, Micro-filled, Micro-hybrid, Nano-fill and Nano-hybrid) and with the invention of novel Silorane-base composites containing different compositions, sandblasting can

produce surfaces with different degrees of surface roughness.⁽⁸⁾

Considering that a comprehensive study on simultaneous evaluation of resin composite surface roughness and bond strength after sandblasting is not available, the present study was performed to compare the impact of resin composite types on bond strength and surface roughness after sandblasting.

Methods and Materials:

This in-vitro experimental study was performed on sandblasted resin composite samples. 44 resin composite discs, comprising of Nano-hybrid (Filtek Z250 xt), Nano-fill (Filtek Z350XT), Micro-hybrid (Filtek Z250) and Silorane-base (Filtek p90) were selected. The discs were placed inside a mold with 6mm diameter and 2mm height, which was fixed firmly on a glass slab. In all samples, the resin composite was placed using a plastic instrument without any contamination and was covered with a Mylar strip before curing. Then a glass slab was placed on the top to provide a smooth surface and to remove the excessive composite. Each sample was light cured with an LED light curing device (Star Light Pro; Mectron, Italy) with 600 mw/cm² intensity and no distance from the surface. The intensity of the device was controlled with a radiometer during each curing. Curing duration was adjusted according to the manufacturer's instruction. After mold removal, all samples were polished with coarse, medium, fine and super fine sofflex discs (3M ESPE) in a way that each disc was in contact with the specimen for 20 seconds under light pressure with back and forth movements. Samples were kept in distilled water at 37 °C for 24 hours. Then, the samples were thermo-cycled for 5000 rounds at 5-55 °C for 30 seconds for each bath with 10 seconds transferring time.⁽¹¹⁾

From 11 samples of each resin composite type, one sample was selected to evaluate the level of surface roughness before and after sandblasting with Atomic Force Microscope (AFM, DME-Denmark) and then the samples were sandblasted with 50 μ aluminum oxide powder (Ronving, Denmark) with the use of micro sandblaster intraoral

Specifications of resin composite types used in the present study

Materials	Composition	Type	Manufacturer
Filtek Z250	Matrix: BISGMA,UDMA,TEGDMA and BIS-EMA Filler: SILICA, Zirconia(0.19-3/3micron,60% by wt)	Microhybrid	3M/ESPE
Filtek Z350XT	Matrix: BisGMA,UDMA,TEGDMA, Ethyl methacrylates Filler: aggregated zirconia/silica fillers(5-20 nm),non aggregated silica fillers,(20 nm;59.5 vol%)	Nanofill	3M/ESPE
Filtek Z250 XT	Matrix: Bis-EMA, Bis-GMA, UDMA, TEGDMA Filler: SiO2 Nanosilica filler, ZrO2/SiO2 Nanoclusters (0.02-0.075 lm) Filled 78.5% by wt	Nano hybrid	3M/ESPE
Filtek p90	Silorane resin Quartz, Yttrium Fluoride(0.47 micron) Filler: Fine particle(60.2% by w)	Silorane base	3M/ESPE

Bis-EMA - ethoxylatedbisphenol-A dimethacrylate; BisGMA- bisphenol A diglycidyl methacrylate;; TEGDMA - triethyleneglycol-dimethacrylate; ; UDMA - urethane dimethacrylate.

sandblasting instrument (Dentoprop Ronving, Denmark) for 5 seconds from 5mm distance at 90 degrees angle. To provide a fixed distance for all samples, they were placed inside a transparent plastic rod with the inner diameter of 6mm and 5mm height along with 2mm space for the sample and 3mm space for sandblasting. ⁽¹¹⁾ All the stages of sandblasting were performed by one operator. In AFM technique, the digital instruments were activated in non-contact mode to obtain topographic images from the selected areas on the desired surfaces. This instrument has been equipped with a scanner with maximum values of 100×100×5µm in xyz dimensions. To measure the values of surface roughness, the tip of the instrument moved across the surface and images were obtained.

The coordinates of three points on the same surface on the center of the specimen were determined and the mean values were used for statistical analysis. A silicon probe with normal constant curvature was used for image taking. The amount of surface roughness (Ra or average height in profile) was reported by the device. ⁽¹²⁾

The surfaces of the remained samples (10 samples from each resin composite type) were

etched with 37% phosphoric acid for 30 seconds and were rinsed with water for 30 seconds and were dried with air pressure from 5mm distance for 10 seconds. ⁽¹³⁾ Adper Single Bond 2 was applied on the surfaces of Micro-hybrid, Nano-fill and Nano-hybrid composites and was cured for 10 seconds. Then, the samples were placed inside an especial aluminum mold with 4mm height and the new resin composites with 2mm thickness were added and cured. In Silorane-base samples, the primer of p90 adhesive system was applied on the surface of old resin composite and was cured for 10 seconds and then the bonding of p90 adhesive system was applied and cured for 10 seconds. Then, the samples were placed inside an aluminum mold with 4mm height and the new resin composites with 2mm thickness were added and cured.

Afterwards, the samples were mounted in molds using self-curing acrylic resins and were placed in universal testing machine (ZwickRoell Z050, Germany) and a force with 1mm/ min speed was applied by a blade to the interfaces of the samples and after observing the first bond fracture between the old and new composites, the shear bond strength was recorded in MPa. ⁽⁷⁾ ANOVA test was used for statistical analysis.

Results:

The obtained values after evaluation of surface roughness in four resin composite types showed that before sandblasting, the maximum surface roughness was related to Nano-hybrid resin composite (Z250xt) which equaled 505 ± 154 nm and the minimum surface roughness was appointed to Micro-hybrid resin composite (Z250) which equaled 94 ± 35 nm. The ANOVA test showed that the values of composites' surface roughness were significantly different before sandblasting ($p < 0.001$).

After sandblasting, the maximum surface roughness was detected in Nano-fill resin composite (Z350XT), which equaled 1997 ± 288 nm and the minimum surface roughness was attained for Nano-hybrid type (Z250xt) that equaled 1284 ± 645 nm, The surface roughness of Z350XT was 713nm more than that of Z250xt. ANOVA test showed that this difference was not statistically significant ($p < 0.4$). (Table 1)

Table 1- Amount of surface roughness (nm) divided by resin composite type

Resin composite type	Before sandblasting		After sandblasting	
	Values	cv	Values	cv
Z250	94±35	37	1303±228	17
Z250xt	505±154	30	1284±645	50
Z350XT	193±77	39	1997±288	14
p90	364±227	62	1414±821	58
P value	P<0.001		p<0/4	

Based on the assessment of the Coefficient of Variation (CV) before sandblasting, homogeneity of Z250xt was the highest (CV=30) and the lowest homogeneity was related to p90 resin composite (CV=60). After sandblasting, the lowest

homogeneity was again related to p90 resin composite (CV=58) and the highest value was related to Z350XT (CV=14). (Table 3 and figure 1, A-H) Also, assessment of the results of shear bond strength test showed that the highest shear bond strength was related to Z250 (37.8 ± 4.6 MPa) and the lowest value was related to Z250XT (7.6 ± 1.9 MPa). ANOVA test proved that this difference was statistically significant ($p < 0.000$) and POST HOC test showed the differences between Z250 group and other three groups as well as the differences between Z350XT and p90 and also the differences between p90 and Z250XT, were all significant ($p < 0.001$). Based on the assessment of the CV, the highest homogeneity was related to Z250 scoring 12 and the highest non homogeneity was detected in Z250XT and equaled 25. (Table 2)

Table 2- bond strength (MPa) based on resin composite type

Resin composite type	Values	Coefficient of variation
Z250	37.8±4.6	12
Z250XT	7.6±1.9	25
Z350XT	30±3.8	12
p90	17.49	22
P value	P<0.000	

Discussion:

Many studies have shown that composite's surface condition plays an important role in the bond strength between the new and aged restorations, and the interstitial bond between resin composite layers decreases gradually due to conditions in oral environment such as humidity and temperature variations.⁽¹⁴⁾ In evaluation of bonding between new and aged resin composite restorations, factors such as resin composite type, surface treatment, interstitial adhesive substance, the age of the former restoration and the interaction between these factors should be considered.

^(8, 15) The new resin composite cannot bond with the old one without surface treating the aged resin composite, and it seems that proper micromechanical bonding on the surface of the old resin composite is the most important factor in achieving high bond strength. ⁽⁷⁾

The results of the present study showed that sandblasting with aluminum oxide particles increased surface roughness in all of the studied resin composite samples and the highest level of surface roughness was related to Z350XT ($1997 \pm 288\text{nm}$) and the lowest amount was related to Z250XT ($1284 \pm 645\text{nm}$). Moreover, the highest bonding strength was for Z250 ($37.8 \pm 4.6\text{ MPa}$), Z350XT ($30 \pm 3.8\text{ MPa}$), p90 ($17.9 \pm 4\text{ MPa}$) and Z250XT ($7.6 \pm 1.9\text{ MPa}$) respectively and these variations were statistically significant amongst all groups.

Based on our findings, no similar study has been conducted on the impact of sandblasting with aluminum oxide powder on the surface roughness of the mentioned resin composites. However, in similar studies the surface roughness of some types of resin composite has been evaluated with different mechanical surface treatment methods.

In a study by Janus et al the surface roughness and morphology of three Nano-composites were evaluated after two different surface treatments with AFM. They concluded that the composition of resin composite especially the amount and size of filler particles affect the surface roughness of different resin composites.⁽¹⁶⁾ This finding is in line with other studies as well as ours.⁽¹⁷⁻¹⁹⁾ Also in the study by Janus et al, the use of Nano particles in the composition of resin composite did not necessarily improve the surface properties of resin composite and this finding is also in line with ours.⁽¹⁶⁾

In a study by Loomas and colleagues, in contrast to our results, Nano-fill resin composite showed the lowest amount of surface roughness after surface treatment.⁽¹⁷⁾ The reason for this difference can be attributed to different resin composite types, surface treatment technique and different aging processes in the two studies.

Duarte et al. concluded that Silorane-base resin composite with the average filler size of $0.55\mu\text{m}$ can have surface roughness similar to Micro-hybrid resin composite with the same filler size.⁽¹⁹⁾ Correspondingly in our study, the amount of surface roughness after sandblasting was reported to be in a close range for Micro-hybrid and Silorane-base composites.

Senawong et al. assessed the surface roughness of Nano-fill and Nano-hybrid composites and found that surface roughness showed no significant difference between polished and non-polished composites, and for Nano-fill resin composite no difference in surface roughness was detected between the two different polishing methods and also in the non-polished surfaces⁽¹¹⁾ which contradicts our findings. This difference can be attributed to the difference between the methods used for surface treatment.

Similar studies have been conducted on the repaired bond strength and the effect of surface roughness on bond strength in resin composites, which have revealed comparable results to the outcomes of our study.⁽¹⁷⁻²⁰⁾ Sinval et al. showed that the highest bond strength was for Micro-hybrid resin composite and the lowest amount of bond strength was related to Nano-hybrid type,⁽¹⁵⁾ which is in line with our findings.

Different studies showed that sandblasting with aluminum oxide significantly increases the micromechanical retention and increases the bond strength after repair,^(7, 14, 15, 20) which were in line with our results indicating that after sandblasting the lowest amount of surface roughness was related to Nano-hybrid Z250XT composite.

Our study indicated that surface roughness significantly increased in the four resin composite types after sandblasting which shows that despite differences in composites regarding the composition and size of fillers, sandblasting with aluminum oxide powder can be a reliable surface treatment method to increase micromechanical retention and repaired bond strength. Nevertheless, shear bond strength doesn't necessarily increase with increased surface roughness. As mentioned before, Micro-hybrid resin composite

with lower surface roughness showed the highest amount of shear bond strength after sandblasting compared to Nano-fill and Silorane-base composites.

Previous studies have shown that the size of fillers can be influential in improving the repaired bond in composites and it seems that larger fillers can improve the bond strength between the new and aged restorations⁽²¹⁾ as it was shown for Micro-hybrid resin composite with larger filler particles even though these larger fillers can lead to higher surface roughness in Z250 compared with other composites.⁽¹¹⁾

In the present study, Silorane-base resin composite was in the third place regarding bond strength and it was in the second place regarding surface roughness after sandblasting. Palasuk et al. stated that bond strength of methacrylate-base resin composite is higher without surface treatment. However, Silorane-base resin composite responds better to surface treatment methods such as sandblasting and provides higher bond strength.⁽²⁰⁾ Similarly, our study showed that Silorane-base resin composite had higher surface roughness after sandblasting compared with Micro-hybrid and Nano-hybrid resin composites. However, lower bond strength compared with Z250 and Z350XT can be attributed to the non-homogenized distribution of surface roughness in p90 composite. Higher bond strength of this resin composite compared with Z250XT can be attributed to the higher amount of surface roughness in p90 in contrast to Z250 and the similarity of surface homogeneity. The reason for the higher roughness of Silorane-base resin composite can be attributed to lower bond strength between the fillers and the matrix which are susceptible to debonding and separation when exposed to aging and surface treatment methods which also can be a reason for surface destruction and increased surface roughness of this composite.⁽²²⁾

Both aging processes in the present study i.e. keeping in distilled water and thermo-cycling can destruct Nano-fill and Silorane-base composites and increase the surface roughness.

As mentioned before, despite less inclination

for water absorption in Silorane-base composites, weaker connection between the fillers and matrix and their debonding during the aging process can lead to higher surface roughness.⁽²³⁾

In laboratory experiments, the shear bond strength between resin composite and etched enamel and primed dentinal surfaces has been reported to be 20 to 30 MPa and the main cause of this bond is micromechanical retention and permeation of resin into enamel and dentin structure.⁽²²⁾ This kind of bonding is formed in etched dentin due to permeation of resin into inter-tubular area and the formation of hybrid layer to the depth of 0.1 to 5 μ m, with a similar mechanism to the creation of surface roughness to provide higher repaired bond strength.^(24, 25) Studies have revealed that proper repaired bond strength in composites is approximately equal to the bond strength between resin composite and etched enamel.⁽²⁰⁾

According to the above statements, three resin composite types in our study (Micro-hybrid, Nano-fill and Silorane-base) had acceptable bond strengths but the bond strength of Nano-hybrid type was below the expected value. The reason may be the different effect of sandblasting on the surface of this resin composite which produces a surface with a very non homogenized roughness distribution, which can lead to abnormal stress distribution on the experimented surface and premature fracture in the sample. Nevertheless, the experimental condition should also be considered because in shear bond strength tests, a wide range of results can be obtained in different parts of the same material.⁽²⁵⁻²⁷⁾ Therefore, further investigations are needed in this regard.

Conclusion:

In the present study, Sandblasting caused a significant increase in surface roughness of the four studied resin composite types. Despite the lowest amount of surface roughness in Micro-hybrid composite, it showed the highest bond strength among other composites after sandblasting.

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Conflict of interests

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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