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Composite Resin Veneer Systems: An In Vitro Study to Evaluate Surface Roughness Changes with Different Surface Treatments and Shear Bond Strength

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ABSTRACT

This study aimed to evaluate surface roughness (SR) changes with surface treatments and shear bond strength (SBS) of two prefabricated and one laboratory-made composite veneer systems. The prefabricated groups, Edelweiss (EDL) and Componeer (CMP) while, SR Nexco (NEX) was a laboratory-made group. A total of hundred twenty samples, comprising 40 samples for each group were divided into four subgroups of surface treatment (n=10): (a) no treatment (control), (b) 9% hydrofluoric acid (HF), (c) abrasion with a high-speed diamond bur and (d) sandblast with aluminum trioxide (Al_2O_3) particles. A profilometer was used to evaluate the SR before and after surface treatments applications. Stereo electron microscope was utilized to assess changes occurred on the surface texture of the veneers. For SBS test, the prepared veneer was uploaded over an epoxy resin mould. Two cylindrical adhesive resins were bonded binary and perpendicular over the inner surface of the veneer and tested using Universal Testing Machine (SHIMADZUTM, Japan). Data was analyzed using One-way ANOVA, post-

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hoc student's t-test and Duncan test with $p<0.05$. One-way ANOVA revealed a significant increase in the SR of all veneer groups treated with a diamond bur and Al2O3 sandblast. NEX group showed higher SR (6.52 ± 0.85) followed by EDL (4.59 ± 0.75) and CMP (4.99 ± 0.67) groups. The significant higher SBS was demonstrated by NEX (22.88 ± 5.2 MPa). EDL exhibited higher bond strength (12.3 ± 3.7 MPa) than CMP (11.75 ± 6.5 MPa). A laboratory-made system produced higher SR enhancement with a diamond bur and superior bond strength.

Keywords: Composite veneer systems, surface roughness changes, surface treatments, shear bond strength

INTRODUCTION

Dental veneers are used to improve the color of discolored teeth and straightening slightly malposition teeth (Christensen, 2004). A dental veneer is defined as a layer of tooth-colored restorative material, usually porcelain or composite resin, attached to the surface by direct fusion, cementation or mechanical retention. Dental veneer systems can be classified according to its material and the mode of clinical usage. Christensen (2004) described the common types of veneer materials were porcelain and composite resin materials. In an earlier article, it was concluded that the mode of the clinical usage could be either direct; which most of the time used composite resin materials, or indirect when the veneer had to be manufactured in a laboratory before its clinical usage (Christensen, 2003). Composite resin veneer can also be classified as a laboratory-made system or prefabricated system (Toh et al., 1987).

Composite resin veneer is the technique of choice in complex rehabilitation cases as reported (Asensio-Acevedo et al., 2013). Indirect composite veneers were used to rehabilitate patients and have been widely used in an aesthetic restorative field due to its excellent properties such as wear resistance, aesthetics, marginal adaptation and enamel control over polymerization shrinkage, lower modulus elasticity and higher capacity to absorb functional stresses of composite restorations. Nandini (2010) reviewed several articles with regards to the improvement in properties of indirect resin composites and concluded that composite veneer could effectively be the alternative to the porcelain veneer in aesthetic dentistry.

The evolution of indirect composite veneer is primarily to improve its polymerization shrinkage which could lead to marginal microleakage, postoperative sensitivity, and recurrent caries (Loguercio et al., 2002). It is also used to supplement ceramic restorations in implant cases or patients with poor periodontal structures who require occlusal coverage. Leinfelder (2005) discovered composite veneer could absorb more occlusal stress compared to the ceramic material. The indirect composites are designed, modeled and cured extra-orally by dental technicians.

Prefabricated composite veneers are made of resin materials with specific polymerizing and finishing techniques. A review article has shown the advantages of composite resin materials are its aesthetic, high bond strength, and superior mechanical properties (Rosenstiel et al.,1998). However, Le Roux and Lachman (2007) concluded several shortcomings of these materials included wear, leakage and discoloration leading to impairment in the aesthetic value of the composite resin over time. Componeer (Coltène/Whaledent AG™, USA) and Elderweiss (Edelweiss, Ultradent Inc™, USA) are the two examples of prefabricated composite veneer systems available in the market. They are manufactured from a nanohybrid composite and are extremely thin veneer (0.3 mm) which allow conservation of tooth structure. Various studies have shown the micro-retentive inner surface ensures a lasting bonding, therefore conditioning of the veneer is not required studies (Gomes & Perdigão, 2014; Gurtu et al., 2016).

Surface roughness is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. A surface treatment is a process applied to the surface of a material to improve its retention form, for example by making it more resistant to corrosion or wear (Abu-Eittah, 2012), Barragan et al. (2014) studied different surface treatments effect on zirconia and composite resin and they found the most common pre-surface treatments used were with several mechanical and chemical agents such as aluminum oxide (Al_2O_3) sandblast, modified tribochemical technique or etching with hydrochloric acid (HF) and ferric chloride.

In a study to assess the different surface treatments effect between zirconia and dentin interface, it was concluded that the surface treatment, either for restorative material or the tooth surface, was considered one of the most common clinical procedures to increase the shear bond strength for the tooth-restoration complex (Abu-Eittah, 2012). With the application of surface treatments, the surface texture, or surface roughness, of the restoration will be increased. It can be described by the number of cavities, porosities, and grooves that have been made over the surface of restoration after treatment, thus, leading to the improvement of the quality of mechanical retention at the tooth-restoration complex. However, many factors deal with shear bond strength such as wettability of the bonding surface, silane application, micromechanical and chemical bonds have to be enhanced beside the surface roughness to achieve higher shear bond strength (Brosh et al., 1997; Schmidlin et al., 2010).

Several methods of surface treatments have been employed to roughening the inner surface of veneers mechanically and chemically. Air abrasion with 50 µm Al_2O_3 particles (Swift Jr et al., 1992), roughening with silicon carbide paper or diamond stones (Joulaei et al., 2012) and etching with HF are the examples of surface treatments available clinically. Other mechanical surfaces roughened like grinding with a diamond disc, abraded with a diamond bur or polishing with red a rubber wheel bur were rarely used (Mohammed et al., 2015).

Sandblasting is considered the most reliable mechanical surface roughened method that was used in these studies (Brosh et al., 1997; Grover & Nandlal, 2015). This method is used either with porcelain, zirconia or composite resin materials. Sandblasting is usually performed with aluminum powder with different sizes and time intervals (Grover & Nandlal, 2015; Su et al., 2015; Zhou et al., 2014).

Several studies utilized chemical agents to roughening a veneer surface (Fuentes et al., 2013; Poskus et al., 2015; Yavuz et al., 2013). Hydrofluoric acid, tribochemical silica coating system and phosphoric acid or salinized are few examples of chemical agents commonly used. Some of the studies used both mechanical and chemical roughening agents (Schmidlin et al., 2010; Zhou et al., 2014). Sandblast with 50μm Al_2O_3 particles is considered the most common mechanical surface treatment (Zhou et al. 2014). Schmidlin et al. (2010) stipulated that an abrasion of the surface with a high-speed diamond bur was considered the most commonly used in a clinical setting. HF with 9% or 12% concentration is commonly used for repairing the ceramic veneers with composite resin restoration. Other means of surface treatment are 98% sulfuric acid etching and Aragon plasma treatment (Ho et al. 2015).

Generally, maximum surface roughened increased the bond strength to the surface (Huang et al., 2013). But this concept has its own limitation, which is related to the restorative materials such as chemical compositions and mechanical properties of the material (Yenisey et al., 2016). This eventually leads to the changes from hydrophilic to hydrophobic properties during the setting of the composite resin cement.

Most of the studies evaluated shear bond strength of porcelain on alloy and tooth structures such as enamel and dentin (Çiftçi et al., 2007). They reported porcelain fused to metal (PFM) showed considreably higher shear bond strength than with an adhesive resin. Another study has experimented their self adhesive resin cement to conventional composite resin cement such as Variolink, Panavia F2.0, RelyX Unicem and Maxcem Elite. The authors found that the shear bond strength of self-adhesive resin cement was inferior compared to conventinal cements (Lührs et al., 2010). Until now, no studies have been investigated the shear bond strength between different types of composite veneer systems.

To date, not many studies have been conducted to evaluate the effect of different surface treatments on the surface roughness and bond strength of prefabricated and laboratory-made composite veneers. Therefore, this study is aimed to evaluate the surface roughness (SR) changes with different types of surface treatment and bond strength between two prefabricated and one laboratory-made veneer systems.

The null hypotheses of this study are (1) type of material and (2) type of surface treatment would demonstrate no difference on the surface roughness and bond strength of composite resin veneer materials.

MATERIALS AND METHODS

This is a laboratory-based experimental study evaluating and comparing the surface roughness (SR) changes of two prefabricated and one laboratory-made veneer systems with different surface treatments. The prefabricated systems were Group EDL (Edelweiss, Ultradent Inc™, USA) and Group CMP (Coltène/Whaledent AG™, USA) while the laboratory-made system was Group NEX (SR Nexco, Ivoclar Vivadent, Liechtenstein).

A total of hundred twenty samples (n=120) were tested in this study. Forty veneers were selected from each group: EDL (n=40), CMP (n=40) and NEX (n=40). Each group was further were assigned to 4 subgroups according to surface treatment methods (n=10):

Group 1: no treatment
Group 2: an abrasion with a high-speed diamond bur
Group 3: 9% hydrofluoric acid (HF)
Group 4: sandblast with aluminum trioxide (Al2O3) particles.

The sample size was estimated based on previous literature (Schmidlin et al., 2010; Swift Jr et al., 1992). All samples were cleaned by an ultrasonic water bath (Renfert SYMBRO, Germany) with plaster solvent chemical solution (Gypsolve, England) to remove any accretion or industrial smear layer. Following that, all samples were dried with non-oily dry air and stored in containers. These samples were treated with four different surface treatments simultaneously.

Surface Treatments

No treatment (Group 1/ control group). Ten veneers from each sample group were randomly selected and kept in the container contains saline water without any treatment and served as a control group.

Abrasion with a high-speed diamond bur (Group 2). Ten veneers from each sample group were abraded with a high-speed oval diamond bur by using turbine hand-piece at a speed of 160,000 rpm. The abrasion area was created in three different points on the inner surface of the veneer. These points were positioned at cervical, medial and incisal with 2 mm distance apart (Figure 1). The procedure was done manually using x 3.0 Galilean dental surgical loupes (Univet Optical Technologies North America Inc., Markham, Canada) to simulate the clinical technique. The position of a diamond bur was parallel to the inner surface with a minimal force for one second at each point.

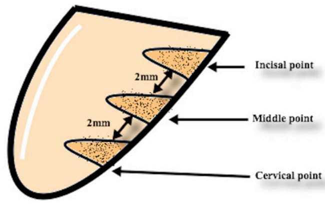

Figure 1. Three different abrasion points on the inner surface of the veneer.

9% Hydrofluoric Acid (HF) Treatment (Group 3). Ten veneers from each sample group were randomly selected and arranged in a line to be treated with 9% HF. By using a micro brush, hydrofluoric acid was applied on the inner surface of each sample for 60 seconds, washed with water spray and dried with non-oily air spray as recommended by manufacturers. Then, all samples were transferred to the labeled containers according to its groups using a plastic tweezer and clinical gloves to avoid contamination before surface roughness measurement.

Sandblast with Aluminum Trioxide (Al2O3) particles (Group 4). Ten veneers from each sample group were randomly selected and sandblasted with aluminum trioxide (Al_2O_3) particles by using sandblast machine (Duostar BEGOTM, Germany) under the pressure of 2 bars, a 10mm distance between the sample and the sandblast tube with 5 seconds exposure time. The sandblast tube was positioned perpendicular over the inner surface of each sample. All samples were cleaned under running water and dried with non-oil air spray to remove any remaining foreign bodies. They were stored in the containers and before surface roughness measurement with a contact profilometer (AMBIOS XP-1, USA).

Surface Roughness (Ra) Evaluation

All samples were transferred to the stage of AMBIOS XP-1 to quantify the Ra value at the three points positions. The mean reading of each veneer was considered as the main Ra value. The profilometer scan was set-up at an equal speed to 0.05mm/sec, 1.5mm length, 10 microns range, 1.0 mg stylus range, filter level equal to 5 and irregular surface as profile type. This set-up was used for all four test groups. The measurement of each sample was done using gloves and a plastic tweezer to prevent any surface contamination. The Ra value was recorded by a device software and the data was transferred to Microsoft Excel sheet 2013.

Scanning Electron Microscope (SEM) Evaluation

After completed of surface roughness testing, each sample from the sample group was selected and observed under Scanning Electron Microscope (SEM) with the magnification powers of 100x and 1000x. The purpose of this procedure was to assess any changes in the surface texture before and after application of the surface treatments. The selected samples were coated with Sputter coater (EdwardsTM, USA) before covering it with a thin layer of conducting material (silver alloy). A conductive coating is required to prevent charging of specimens with an electron beam in conventional SEM mode of high vacuum and voltage.

Shear Bond Strength Testing

The study was further elucidated to investigate which veneer groups exhibited the highest shear bond strength. Samples were carefully selected and were utilized from each veneer system (n=10); CMP, EDL, and NEX, that had undergone surface treatment and showed the superior Ra values. The veneer was trimmed with diamond saw under cooling water to produce a flat bonding surface and then cut into a rectangular shape measured 8mm length with 5mm width. The veneer was placed horizontally on a translucence rectangular box filled with epoxy resin (Maricon, Romania) with the inner surface of each veneer was positioned away from the epoxy resin.

Prior to the placement of an adhesive materials, the veneer surface was etched for 20 seconds to remove any debris, washed under running water and dried using air spray. Two mould frames, each measured 2.5mm in diameter and 1.5mm thickness were created by a specific leather puncture and an acid-resistant adhesive tape were located on the inner surface of the veneer. The frames were loaded with an adhesive agent, light cured according to the manufacturer's guide to produce two adhesive cylinders. A magnifying dental loupe was used to check any defect on the adhesive cylinders and were discarded if any defect found. The calculation of sample size for SBS testing was based on the previous studies (n=10*2=20) (Abo-Hamar, 2013; Khamverdi et al., 2013; Pahlavan et al., 2013; Perdigão et al., 2013; Puvoravan et al., 2013). Shear bond strength was determined by Universal Testing Machine (SHIMADZU™, Japan). The shear bond set-up pin of the machine was perpendicularly positioned over the cylinder and parallel to the veneer inner surface. A shear load was applied at a crosshead speed of 1 mm/min until its failure. The micromechanical bond strength value is indicated in Figure 2.

Statistical Analysis

The data was recorded by the Statistical Package for the Social Sciences (SPSS) version 17.0 (SPSS Inc. Chicago, Illinois, USA). Descriptive statistics including means and standard deviations were calculated for each group, compared and analysed using One-way analysis of variance (ANOVA) to compare the significance difference of surface roughness and shear bond strength between groups. Post-hoc, student t-test was used to determine which veneer group showed the highest Ra value. Two-way ANOVA was employed to analyze Ra value which comparing between two dependent variables (three veneer groups and four surface treatments). Student t-test was also used to evaluate the most superior shear bond strength among the veneer systems. A statistically significance difference was determined at a 95% confidence level with a p-value of ≤ 0.05.

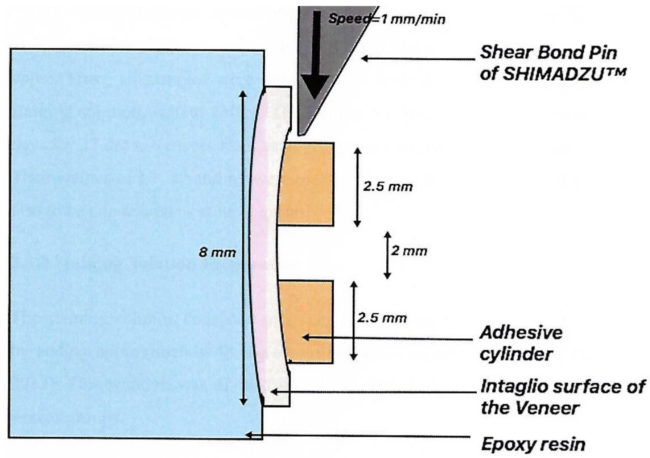

Figure 2. The diagram showed the position of adhesive agent cylinders in relation to shear bond pin set-up.

RESULTS

Three methods of comparison were conducted in this study. The first comparison was done between the sample groups without any application of surface treatments with the aimed to evaluate any significance of Ra value. Figure 3 as indicated by Group 1 shows the Ra values of all samples prior to surface treatments. Descriptive analysis demonstrated the highest Ra value came from Group CMP (1.58 ± 0.66) followed by Group EDL (0.57 ± 0.25) and Group NEX (0.38 ± 0.18).

The second comparison was when the sample groups were treated with the tested surface treatments. The objective was to evaluate any significant difference of the Ra value upon receiving three different methods of surface treatments. Bar chart in Figure 3 shows the highest Ra value was from Group 2 with Group NEX (6.52 ± 1.20) followed by Group CMP (4.99 ± 0.94) and Group EDL (4.59 ± 1.05). Meanwhile, the lowest Ra value was from hydrofluoric acid surface treatment with Group NEX (0.38 ± 0.12), Group EDL (0.97 ± 0.67) and Group CMP (1.36 ± 0.32). Among the sample groups, Group NEX exhibited the highest Ra value followed by Group CMP and Group EDL.

Based on the outcome of the surface treatment methods, air abrasion with an oval-shaped high-speed diamond bur exhibited the highest Ra value. Therefore, the third objective is to use this method for further investigation the SBS among the veneer groups. NEX group showed the highest SBS (22.88 ± 5.2 MPa) as compared to prefabricated veneer groups; EDL (12.31 ± 3.7 MPa) and CMP (11.75 ± 6.5 MPa) with p-value <0.05. There was no significant difference between the EDL group and the CMP group, p<0.05.

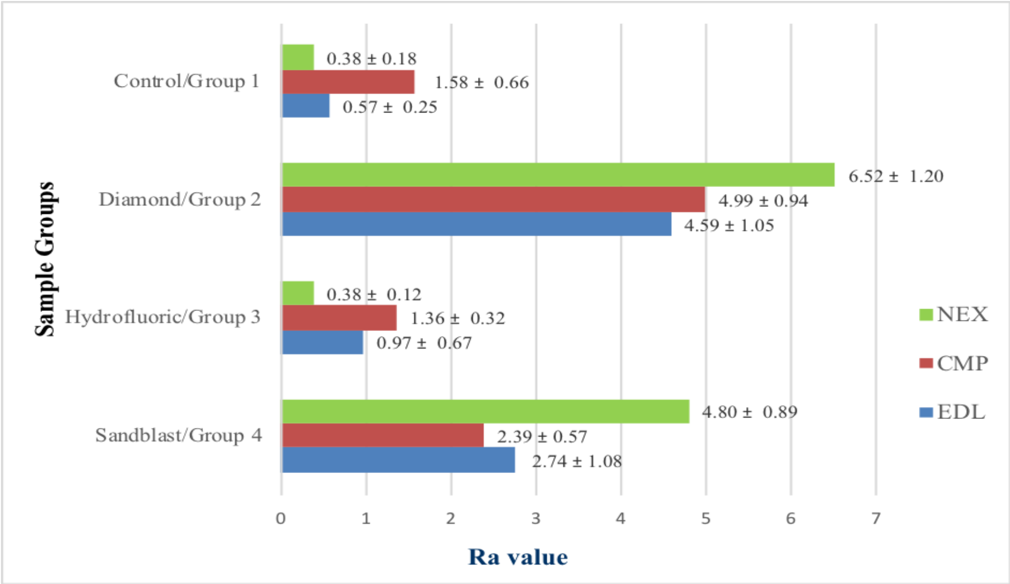

Figure 3. The mean values and standard deviation of surface roughness (Ra) for each surface treatment of the three sample groups.

Statistical Analysis with One-way ANOVA and Student t-test

Non-treatment group (control group). One-way ANOVA exhibited a significant difference for all Ra values between samples in Group 1 (Table 1). Table 2 shows the significant differences between Group CMP with Group EDL and Group CMP with Group NEX ($p<0.05$). No significant difference was recorded between Group EDL with Group NEX.

Surface Treatment groups (test groups). Irrespective of the sample groups, one-way ANOVA revealed a significant difference of Ra values when the sample surface was treated by the three surface treatments (Table 3). Student's t-test was carried out for each surface treatment method with the sample groups. Table 2 displays a significant difference of SR value by Group 2 between Group NEX with Group EDL ($p=0.01$) and Group CMP ($p=0.05$). Nevertheless, no significant difference was found between Group EDL with Group CMP ($p=0.389$) regardless of the surface treatment methods. Table 2 shows similar significance results for Group 3 and Group 4 respectively ($p<0.05$).

Two-way ANOVA exhibited no significant difference of Ra value by NEX and CMP veneer systems prior to the treatment or after treatment with Group 3. The same result was found with NEX and EDL systems, no significant difference in Ra value was noted prior to the treatment and after treatment with Group 3. Group 2 and Group 4 demonstrated almost similar surface roughness for NEX and EDL veneer systems. Generally, it was found that both prefabricated and a laboratory-made group showed significantly higher RA value with Group 2 and Group 4 but not with Group 3 (Table 4) ($p<0.05$).

Table 1
One-way ANOVA for the surface roughness values on non- treated test groups

Surface treatment methods	St. Error	Significant F>C	P-value
Group 1	0.1	Yes	0.000

Note. Average surface roughness (Ra) varies across values of non-treatment and the three treatment veneer groups (α =0.05).

Table 2
Student's t- test for surface roughness values between surface treatment methods with the three veneer groups

Surface Treatment Methods	Sample Groups		St. Error	Significant t>C	P-value
Group 1	CMP	EDL	0.2	Yes	0.000
		NEX	0.2	Yes	0.000
	EDL	CMP	0.2	Yes	0.000
		NEX	0.1	No	0.068
	NEX	CMP	0.2	Yes	0.000
		EDL	0.1	No	0.068
Group 2	CMP	EDL	0.2	No	0.389
		NEX	0.3	Yes	0.005
	EDL	CMP	0.2	No	0.389
		NEX	0.3	Yes	0.001
	NEX	CMP	0.3	Yes	0.005
		EDL	0.3	Yes	0.001
Group 3	CMP	EDL	0.1	No	0.113
		NEX	0.1	Yes	0.000
	EDL	CMP	0.1	No	0.113
		NEX	0.1	Yes	0.000
	NEX	CMP	0.1	Yes	0.000
		EDL	0.1	Yes	0.000
Group 4	CMP	EDL	0.2	No	0.375
		NEX	0.3	Yes	0.000
	EDL	CMP	0.2	No	0.375
		NEX	0.3	Yes	0.000
	NEX	CMP	0.3	Yes	0.000
		EDL	0.3	Yes	0.000

Table 3
One-way ANOVA for the surface roughness values by each surface treatment method on the test veneer groups

Surface Treatments Methods	St. Error	Significant F>C	P-value
Group 2	0.2	Yes	0.000
Group 3	0.1	Yes	0.000
Group 4	0.3	Yes	0.000

Note. Average surface roughness (Ra) varies across values of non-treatment and the three treatment veneer groups (α =0.00)

Table 4
Two-way ANOVA analysis for surface roughness values and surface treatments between a laboratory-made and two prefabricated veneer groups

G1	G2	Surface treatment		St. Error	Significant t>C	P-value
NEX	CMP	Group 1	Group 2	0.4	Yes	0.000
		Group 1	Group 3	0.1	No	0.374
		Group 1	Group 4	0.3	Yes	0.000
		Group 2	Group 3	0.4	Yes	0.000
		Group 2	Group 4	0.3	No	0.143
		Group 4	Group 3	0.3	Yes	0.000
	EDL	Group 1	Group 2	0.4	Yes	0.000
		Group 1	Group 3	0.1	No	0.103
		Group 1	Group 4	0.3	Yes	0.000
		Group 2	Group 3	0.4	Yes	0.000
		Group 2	Group 4	0.3	No	0.844
		Group 4	Group 3	0.3	Yes	0.000

Scanning Electron Microscope (SEM)

The SEM was further used to ascertain the changes in the surface texture of the inner surface for each sample group after various surface treatments. Under 1000x magnification power, the surface texture of a randomly selected sample from each sample group was evaluated and compared between treated and non-treated groups as depicted in Figure 4, 5 and 6.

It was clearly observed that oblique stripes, pores, and cavities were established on the inner surface of the sample when treated with Group 2 and Group 4 methods as indicated by a black arrow in Figure 4b, 4d, 5b, 5d, 6b and 6d. In contrast, the Group 3 surface treatment demonstrated a relatively smooth surface and minimum irregularities on the inner surface of all sample groups (a black arrow in Figure 4c, 5c, 6c).

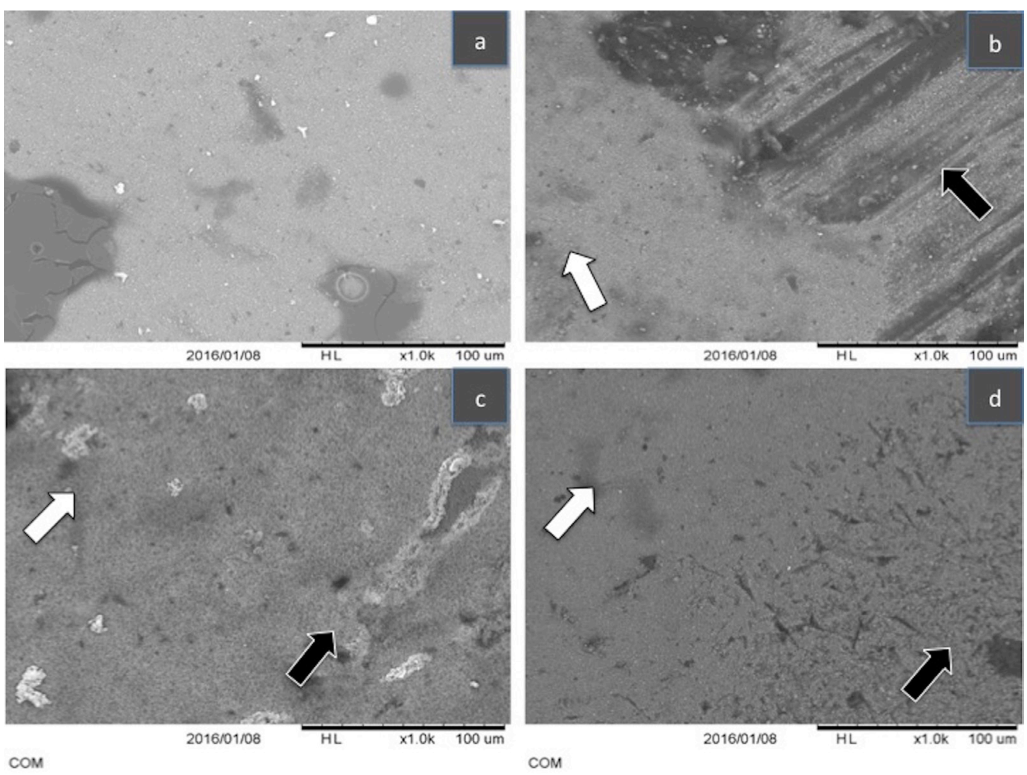

Figure 4. SEM images of the inner surface of CMP veneer before and after various surface treatments.

a) Group 1 (control), no treatment
b) Group 2 (abrasion with a high-speed diamond bur)
c) Group 3 (hydrofluoric acid (HF) treatment) presented with a smooth surface and minimum irregularities
d) Group 4 (sandblast with Aluminum Trioxide (Al2O3) particles)

The white arrow indicates the image before surface treatment and the black arrow indicates after various surface treatment

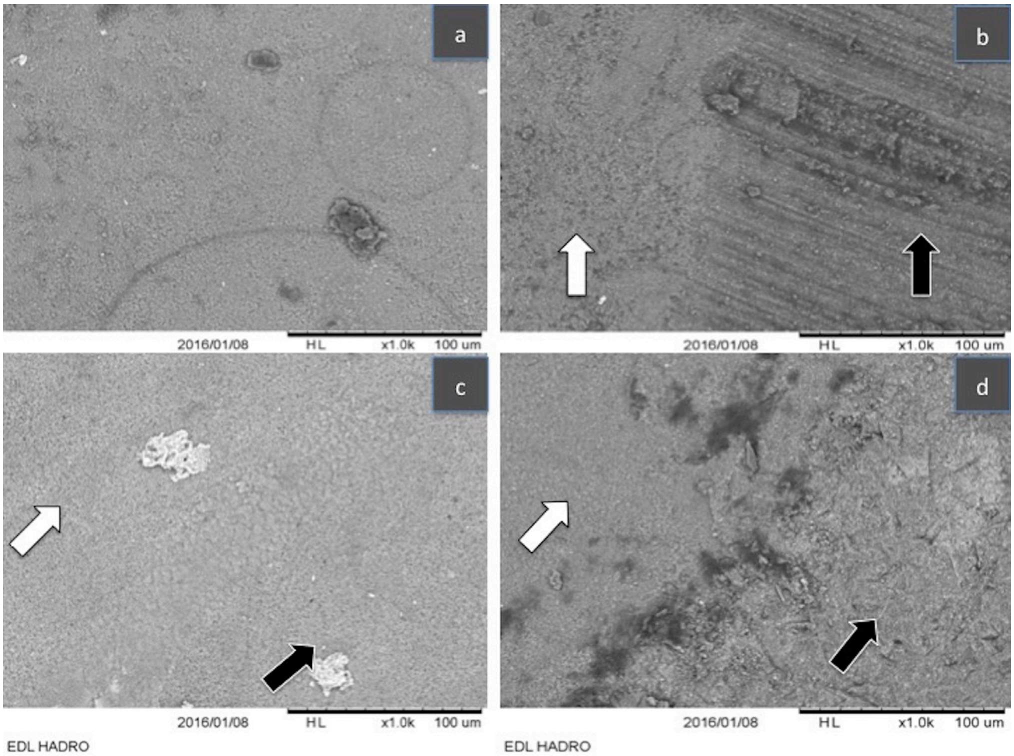

Figure 5. SEM images of the inner surface of EDL veneer before and after various surface treatments.
a) Group 1 (control), no treatment
b) Group 2 (abrasion with a high-speed diamond bur)
c) Group 3 (hydrofluoric acid (HF) treatment) presented with a smooth surface and minimum irregularities
d) Group 4 (sandblast with Aluminum Trioxide (Al2O3) particles)

The white arrow indicates the image before surface treatment and the black arrow indicates after various surface treatment

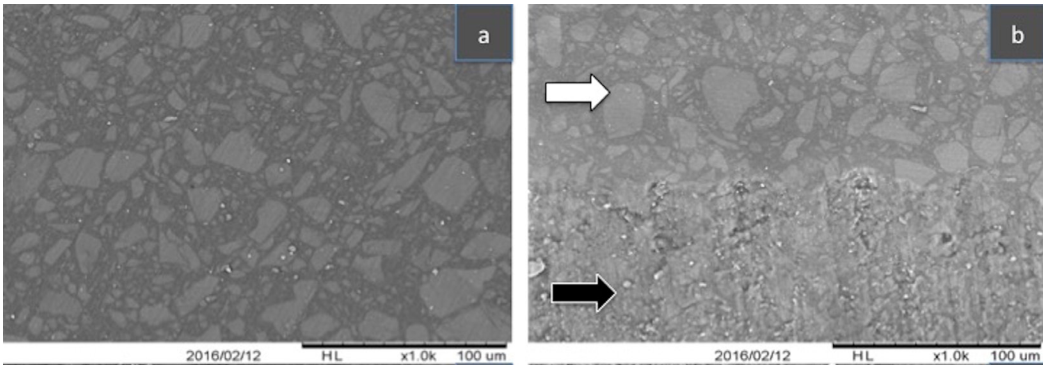

Figure 6. The SEM images of the inner surface NEX veneer before and after the surface treatments.
a) Group 1 (control), no treatment
b) Group 2 (abrasion with a high-speed diamond bur)

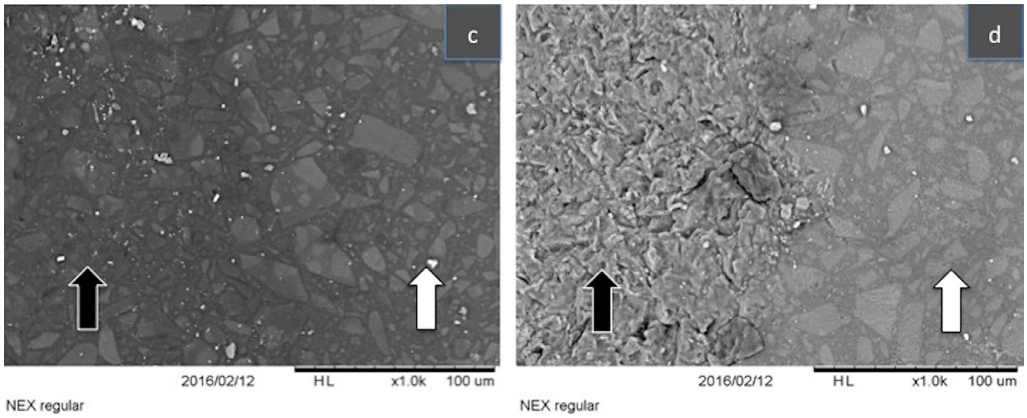

Figure 6 *(Continued)*
c) Group 3 (hydrofluoric acid (HF) treatment) presented with a smooth surface and minimum irregularities
d) Group 4 (sandblast with Aluminum Trioxide (Al2O3) particles)

The white arrow indicates the image before surface treatment and the black arrow indicates after various surface treatment

Table 5
Student t- test for shear bond strength values within veneer groups

		Test Statistic t	Critical Value @5 % C	St. Error	Significant t>C	P-value
CMP	EDL	0.302	2.042	0.9	No	0.765
	NEX	5.515	2.042	1.4	Yes	0.000
EDL	CMP	0.302	2.042	0.9	No	0.765
	NEX	6.803	2.042	1.2	Yes	0.000
	CMP	5.515	2.042	1.4	Yes	0.000

Statistical Analysis with One-way ANOVA and Student t-test

One-way ANOVA revealed a significance different of SBS was found between 2 types of veneer systems. Table 5 shows the significant differences between Group CMP and Group EDL with Group NEX (p=0.00). No significant difference was recorded between Group CMP and Group EDL (p>0.05)

DISCUSSION

This is an *in-vitro* study focusing on the surface roughness changes of two types of composite resin veneer systems with three different surface treatments. The surface roughness is important to ensure a good mechanical pre-treatment bonding between restorative materials and adhesive systems.

Surface treatments were applied to the inner surface of these samples with the aimed to investigate the best method to enhance its mechanical or chemical retention, which is indicated by the increased Ra value. Surface treatments included an abrasion with a high-speed diamond bur, acid etching with 9% HF and sandblasting with 50 um aluminum trioxide (Al_2O_3) particles were tested. A descriptive analysis was carried out on the control group prior to the surface treatments applications primarily to assess the pre-treatment Ra value for each veneer group. Based on Figure 3 (Group 1), it could be suggested that CMP veneers demonstrated the roughest surface prior to its treatments.

One-way ANOVA showed significant differences of Ra values by three sample groups when treated with various types of surface treatments. Comparing the materials within the same surface treatment methods revealed that Group NEX generally demonstrated the highest Ra value especially when treated with Group 2. It could be suggested that a laboratory-made veneer system has superior Ra value than prefabricated veneer systems. With regards to the prefabricated veneers, students t-test analysis revealed no significant difference of Ra value was found between Group CMP and Group EDL. This indicates that both groups have almost the same quality of surface roughness irrespective of the methods of surface treatments.

This study also demonstrated the application of surface treatments significantly increased the quality of surface roughness of composite resin veneers when compared to a control group (Figure 3, Table 4). Güngör et al. (2016) and Neis et al. (2015) stipulated an increased surface roughness improves mechanical interlocking on the bonding surface and its bond strength on dental ceramics. Surface treatments have been shown to improve the bond strength of resin composite to CAD/CAM resin-ceramic hybrid materials for repair (Elsaka, 2015; Stawarczyk et al., 2015; Wiegand et al., 2015). Grinding with a diamond bur generated the highest surface roughness among the surface treatment methods on resin composite bonded to resin- ceramic hybrid materials (Güngör et al., 2016). The result of the present study is in accordance with those studies.

Two-way ANOVA revealed a significant increase in Ra value as showed by Group 2 and Group 4 surface treatments ($p<0.05$). It can be concluded that both methods were effective to increase the mechanical retention form for all sample groups (Table 4). However, it was a clear evidence (Roeters, 2000) that a major disadvantage of sandblasting was the aerosol of fine abrasive particles that will contaminate a wide area of the operatory, which might be harmful to patients and operators. Therefore, it is recommended to abrade the inner surface of veneer with a diamond bur as a surface pre-treatment prior to cementing process to obtain a stronger mechanical bond between the two structures. Moreover, this method can be easily applied and produce a faster result clinically. Nevertheless, an air abrasion with silica and (Al_2O_3) sandblast for 15s at a distance of 10 mm has been shown to increase surface roughness with PEEK composite resins during composite repairs (Poskus et al., 2015; Zhou et al., 2014).

In this study, 9% hydrofluoric acid produced the lowest Ra value for the tested samples. No significant difference was exhibited between Group 3 and Group 1. It can be extrapolated that 9% HF surface treatment is not chemically effective in improving the surface roughness of the composite veneers. This finding is consistent with previous studies (Swift Jr et al., 1992; Zhou et al., 2014).

The sample surfaces treated with hydrofluoric acid yielded the lowest RA value. Therefore, it could be suggested that the hydrofluoric acid is not recommended to be used as a routine pre-treatment method. Furthermore, hydrofluoric acid has a corrosive effect and a contact poison. A meticulous application technique is needed to prevent detrimental side effects, such as acid burns and necrosis of the underlying soft tissues as previously reported (Asvesti et al., 1997).

It was clearly evidenced under SEM with 1000x magnification, that oblique stripes, pores, and cavities were established on the inner surface of the sample when treated with Group 2 and Group 4 methods. This is shown by a black arrow in Figure 4b, Figure 4d, Figure 5b, Figure 5d, Figure 6b, Figure 6d compared to a white arrow (before the treatments) in the same figures. In contrast, Group 3 surface treatment demonstrated a relatively smooth surface and minimum irregularities on the inner surface of all sample groups as demonstrated by a black arrow in Figure 4c, Figure 5c, Figure 6c than a white arrow (before the application of Group 3). Their surface textures showed the same appearance towards different surface treatments. The differences in the size, volume, and shape of the fillers of the three composite veneer systems possibly did not significantly affect their surface roughness. This finding is concurrent with previous studies (Ho et al., 2015; Schmidlin et al., 2010).

A study has shown that the surfaces treated with hydrofluoric acid showed undercuts when the filler were dissolved and removed from the matrix (Zhou et al., 2014). This finding was quite similar to the present study even with a different concentration of the hydrofluoric acid. The weak bond strength of the HF on the pre-treated restorations could be attributed by the low surface roughness after treatment as proven in the present study.

The veneer samples which were treated by Group 2 were chosen to undergo shear bond strength test (SBS). The objective was to investigate which type of veneer systems that produced superior micromechanical bonding with its adhesive agent. According to ISO 10477 requirements, the minimum acceptable shear bond strength value is at least 5 MPa (Sarafianou et al., 2008). Matsumura et al. (2001) suggested the minimum of 10 MPa of SBS for resin to metal bonded had to be achieved to consider as clinical satisfactory. But, no literatures had been mentioned on the SBS for resin to resin.

The adhesive systems used for both prefabricated veneers as recommended by the manufacturer, Multilink Automix (Ivoclar Vivadent, USA) were selected to be used as an adhesive system on the laboratory-made veneer system. Völkel (2004) postulated the value of SBS for this adhesive agent was between 20-25 MPa as compared to the other agent such the self-curing RelyX Unicem (13.08 ± 3.61 MPa) (Moghaddas et al., 2017). With this evidence, we chose Multilink Automix adhesive agent due higher bond strength on both enamel and dentin structures. However, until now, no study has been conducted to evaluate SBS from resin to resin. In this study, the SBS for NEX group was 22.8 ± 5.0 MPa followed by EDL group; 12.3 ± 3.7 MPa and CMP group; 11.75 ± 6.5 MPa. One way ANOVA showed NEX group was significantly higher than the other two prefabricated groups. The significant difference could be attributed to many factors such as the type of adhesive system for each group and the size of fillers in veneer resin material itself. Perdigão et al. (2013) evaluated the micro shear bond strength of the prefabricated veneer system (Componeer™) and compared it with IPS and Cerinate (Ceramic based veneer). He found that the μSBS of Componeer is 15.2 ± 2.5 MPa which relatively is the same in the present study.

Several studies reported volume, weight, types and the size of fillers affects shear bond strength on composite resin (Gallo et al., 2001; Kim et al., 2002; Miyazaki et al., 1995). Further studies need to be carried out on shear bond strength of other methods of surface treatment such as sandblast with Al2O3 particles or 9% HF treatment. The composition of a laboratory-made veneer should interestingly be investigated to indicate its mechanical properties.

Few limitations have been discovered in this study such as limited resources of technical information related to the prefabricated veneer systems, thus, it led to the restriction in comparing the outcome of the present study. The future study also needs to take into consideration of the cost involved if it cracks during the preparation of the samples.

CONCLUSION

Based on the result of this study and within the limitations described, a laboratory-made veneer system had exhibited superior surface roughness than prefabricated veneer systems when treated with different types of surface treatments. Group NEX demonstrated the highest surface roughness value followed by Group CMP and Group EDL. Among the surface treatments tested, an abrasion with a high-speed diamond bur showed the best method to roughening the inner surface of composite veneers followed by sandblasting with aluminum trioxide (Al_2O_3) particles and 9% HF. This study also showed 9% HF agent did not produce any significant effect on the surface roughness and almost similar texture with the non-treated surfaces. The laboratory-made veneer system achieved the highest mean shear bond strength. EDL and CMP veneer systems appeared to be almost similar bond strength and it conveyed no statistical advantage between each other.

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