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The effects of various surface treatments on the shear bond strengths of metal Brackets to Restored Teeth by two different Composite

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ABSTRACT

Background: The purpose of this study was to determine the shear bond strength of metal brackets bonded to restored teeth using methacrylate and silorane based composites in different methods of composite surface preparation. *Materials and methods:* After cutting the class V cavities at the buccal surfaces of 112 acrylic teeth; half of the teeth were restored with Filtek Z-250 composite and the other half with Filtek P-90 composite. Composite surface in both groups were prepared using 4 surface preparation methods: 1- Diamond bur cutting + Acidic etching; 2- Diamond bur cutting + Acidic etching +; 3-air abrasion 4-air abrasion + Silane, and brackets were bonded to teeth. After being stored in water and applying thermal cycles, the shear strength of the brackets bonded to composite was calculated in the universal testing machine. The amount of residual adhesive and resin was determined with a 5-part index. Data were compared using one-way ANOVA in terms of preparation methods and pairwise comparisons were performed by Tukey test. *Findings:* The mean bond strength of brackets to the Filtek Z-250 composite in preparation methods of the groups was 1- 16.36 ± 5.32; 2- 13.11 ± 4.08; 3- 12.74 ± 5.21; 4- 13.16 ± 3.82 MPa; and for the Filtek P-90 composite was 1- 11.7 ± 3.54, 2- 8.2 ± 3.25, 3- 10.41 ± 2.25 and 4- 10.56 ± 3.04 MPa. In all preparation methods, the brackets yielded sufficient bond strength to the composite. In the Filtek P-90 composite surfaces, a greater bond strength was observed in diamond bur + acid etching method ($p < 0.02$). *Conclusion:* Despite the lower bond strength of metal brackets to composite surfaces, due to their acceptable range and the small amount of residual adhesive, metal brackets were acceptably bonded to the surfaces of teeth restored by silorane-based composite in all composite preparation methods.

Keywords: Shear bond strength, Silorane-based composite, Methacrylate-based Composite, Surface Preparation

1. INTRODUCTION

At present, the number of adult patients requesting orthodontic treatment is increasing and has grown rapidly (Proffit et al., 2013). Recent orthodontic therapies require the ability of the orthodontic appliance to bond with non-enamel surfaces such as resin composite, amalgam and porcelain, and therefore achieving a reliable bond to non-enamel surfaces of the teeth is important (Jordan, 2007).

Most composites in restorative dentistry are based on the radical polymerization of methacrylates (Feilzer et al., 1987). In methacrylate-based composites, the chemical bonding of a composite layer to another layer requires the reaction of methacrylate reactive groups of these two layers (Van Kerckhoven & Lambrechts, 1982). These methacrylate reactive groups are placed in the oxygen-inhibited layer of composite resins polymerized at the composite surface and allow the composite to be deposited in the cavity in layers, and each individual layer is polymerized without affecting the bond strength of the next layer (Boyer et al., 1984; Staxrud & Dahl, 2011). The composite that has been aged, finished or contaminated with saliva, lacks this oxygen inhibited layer at its surface (Staxrud & Dahl, 2011; Costa et al., 2010). The half-life of the non-polymerized resin layer in the methacrylate groups remaining in the composite at C ° 37 is only 50 hours (Burtscher, 1993). Clinical finishing of the surface of restorations also removes the reactive monomers mechanically (Staxrud & Dahl, 2011), and in this condition, the chemical bond strength between the new composite and the composite on the tooth surface is reduced. Indeed, the composite bond strength of a new composite on the composite that lasts a week would be only 23% to 47% of the normal condition (Boyer et al., 1984).

Restorations performed on the buccal surfaces are usually made by methacrylate-based composites, but due to the introduction of Silorane composites and their desirable properties, orthodontists will no doubt be confronted with teeth repaired by these composites in the future, of course with few clinical information about them (D'Alpino et al., 2011; Wiegand et al., 2012; Hakiminya and Parnian, 2018; Upikang and Amiri Dogaheh, 2019).

Several composite surface preparation techniques have been proposed to increase the bond strength of brackets to the composite surface of the teeth (Viwattanatipa et al., 2010; Eslami, and Sarlak, 2018). These techniques are divided into two mechanical and chemical types. Mechanical methods include creating superficial roughness on composite surface by bur cutting, sandblasting, silica coating or by air abrasion, and chemical methods including the use of phosphoric acid, hydrofluoric acid, silane or various adhesives (Bayram et al., 2011; Eslamian et al., 2011; Bishara et al., 2003).

The purpose of this study was to compare the shear bond strength of orthodontic brackets bonded to the restored teeth with methacrylate based composite (Filtek Z-250) and Silorane-based composite (Filtek P-90) using different preparation methods for composite surface and determining the fracture pattern between the bracket and composite on the tooth surface.

2. MATERIALS AND METHODS

In this experimental study, buccal surfaces of 112 acrylic central teeth from Ideal Makoo Company were selected and class V cavities with 2 mm margin from incisal, distal, mesial and cervical edges, available with a depth of 3 mm, were carved by ethical code (IR.AJUMS.REC.1397.930).

Samples were randomly divided into two groups of 56. Then, they were etched using 37% phosphoric acid gel (3M ESPE etching fluid) (Schmage et al., 2003). Subsequently, all of the samples were mounted to the acrylic block in order to better control the processes (Eslamian et al., 2011). one group of specimens was restored using Methylacrylate based composite (Filtek Z-250, 3M ESPE, St Paul, MN, USA) and the other group using Silorane-based composite (Filtek P-90, 3M ESPE, St Paul, MN, USA), by implementing the bonding system used for each of the composites according to the order by the manufacturer, and by exposing lighting with the light curing unit (Ortholux LED 3M Unitek-USA). For the aging process, all specimens were kept in water at 37 ° C for 35 days. Samples of the two recent groups were then divided into four subgroups:

1. Diamond bur cutting + etching by phosphoric acid 37%
2. Diamond bur cutting + etching by phosphoric acid 37% + Silane
3. Air abrasion (Micro-etcher Danvile Engineering), CA, USA
4. Air abrasion + Silane

After surface preparation, the orthodontic brackets of central tooth (018 StandardAmerican Ortho) (32.3-28.4 mm dimensions) were bonded to the teeth using 3MUnitek orthodontic composite. The samples were stored in water at 37 ° C for 35 days (Brunharo et al., 2013) and then placed in a thermocycling machine (Delta TPO2, Nemo, Mashhad, Iran) under 100-cycle thermal cycling process at 55-5 °C (Brunharo et al., 2013). In the bracket slot of all specimens, a small piece of stainless steel (0.021 × 0.025-inch 3M Unitek) was placed to minimize bracket deformation during the debonding process, and was closed by 3M Unitek elastomeric ligature. The shear strength of the brackets bonded to the composite was measured with an electromechanical universal testing machine (K-21046, Walter + bai, Switzerland) with a speed of 1 mm / min, and by force applied between the bracket and composite. Debonding forces were measured and recorded in Newton. Then, the shear bond strengths were calculated using the force (N) divided by the cross-section (mm2) in MPa.

After debonding the specimens, the teeth and brackets were evaluated using a stereomicroscope with a magnification of 50X and the ARI (Adhesive Remnant Index) was determined according to the following grading from zero to 4 (Zimmerli et al., 2010):

1. Grade Zero: Lack of adhesive and resin on the composite surface
2. Grade 1: Less than 50% adhesive and resin residue on the composite surface
3. Grade 2: More than 50% adhesive and resin residue on the composite surface
4. Grade 3: 100% adhesive and resin residue on the composite surface
5. Grade 4: Restoration Failure

Two-way ANOVA was used to determine the effect of composite agent used in class V cavity restoration and composite surface preparation method, and one way ANOVA was used to judge the difference in bond strength values in each composite group according to different preparation methods. Considering the significance of the results of one-way ANOVA test in the Filtek P-90 composite group, a pairwise comparison of the subgroups was performed using Tukey's multiple comparison test. A comparison of the ARI index frequency in the four groups in each of the Silorane and based composites was also performed with the nonparametric Kruskal-wallis test.

3. RESULTS

The results of this research are summarized in Tables 1 through 4:

1. The mean shear strength of the brackets bonded to composite surfaces for the methacrylate based composite (Filtek Z-250) was 76.4 ± 84.13 MPa and for the Silorane based composite (Filtek P-90) was 24.3 ± 22.10 MPa (in all preparation methods), which showed that bond strength in methacrylate based composite was significantly higher than that of the Silorane based composites (P <0.0001).
2. Two-way ANOVA showed that there was no statistically significant difference in the shear strengths of metal brackets bonded to the Filtek Z-250 composite surfaces after preparation with different methods (p = 15.0) (Table 1, Fig 1).
3. There was a statistically significant difference in the shear strengths of the brackets bonded to the Filtek P-90 composite surfaces following preparation by different methods (p <0.03) (Table 2, Fig 2).
4. The results of Tukey's multiple comparison test showed significant differences in the shear strengths of the brackets bonded to the Filtek P-90 composite surfaces in the preparation methods including diamond bur cutting + acid etching and diamond bur

cutting + acid etching + silane application (p <0.02), and In other cases, there were no significant differences between the groups: diamond + etching and air abrasion (p = 68.0); diamond bur cutting + acid etching and air abrasion + silane application (p = 76.0); diamond bur cutting + etching + silane application and air abrasion (p = 24.0); Diamond bur cutting + acid etching + silane application and air abrasion + silane application (p = 0.19) and also between air abrasion and air abrasion + silane application (p = 99.0) Table 2).

5. The frequency of different ARI indexes in the Methylacrylate based composite group (Filtek Z-250) and Silorane based composite (Filtek P-90) in different preparation methods is presented in Tables 3 and 4.
6. According to the Kruskal-wallis nonparametric test results, there was no significant difference in ARI scores in different preparation methods for methacrylate based composite surfaces (Table 3) (p = 34.0).
7. According to the recent test, there was a significant difference in ARI scores in different preparing methods for Silorane based composite surfaces (Table 4) (p <0.008).

Table 1 shear bond strength of the brackets bonded to composite surfaces for the methacrylate based composite (Filtek Z-250) surfaces after preparation with different methods in MPa.

surface preparation method	mean shear strength	Standard deviation	Standard error	% 95 mean confidence interval		min	max
	Shear bond			Lower limit	Upper limit		
Diamond bur + acid etch	16.36	5.32	1.42	13.28	19.43	7.38	23.7
Diamond bur + acid etch + Silane	13.11	4.08	1.09	10.76	15.47	7.41	20.19
Air abrasion:	12.74	5.21	1.39	9.73	15.74	5.68	20.83
Air abrasion + silane	13.16	3.82	1.02	10.95	15.37	6.24	15.31
							(p=0.15)

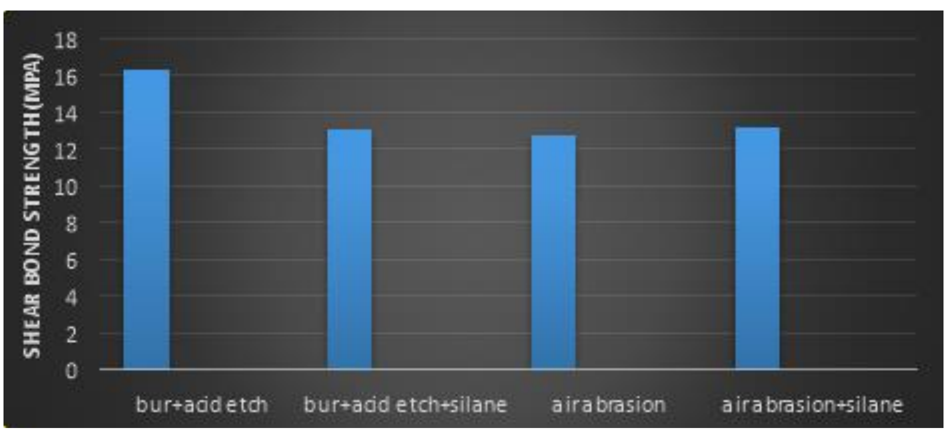


Figure 1 95% confidence interval mean shear bond strength of the brackets bonded to composite surfaces for the methacrylate based composite (Filtek Z-250) surfaces after preparation with different methods in MPa.

Table 2 shear bond strength of the brackets bonded to composite surfaces for the Silorane based composite (Filtek P-90) surfaces after preparation with different methods in MPa.

surface preparation method	mean shear strength	Standard deviation	Standard error	% 95 mean confidence interval		min	max
	Shear bond			Lower limit	Upper limit		
Diamond bur + acid etch	11.7	3.54	0.95	9.66	13.75	8.21	20.58
Diamond bur + acid etch + Silane	12.2	3.25	0.87	9.33	14.08	9.04	19.33
Air abrasion:	10.41	2.25	0.6	9.11	11.71	7.16	12.98
Air abrasion + silane	10.56	3.04	0.81	8.81	12.32	5.32	16.84
	(p<0.002)						

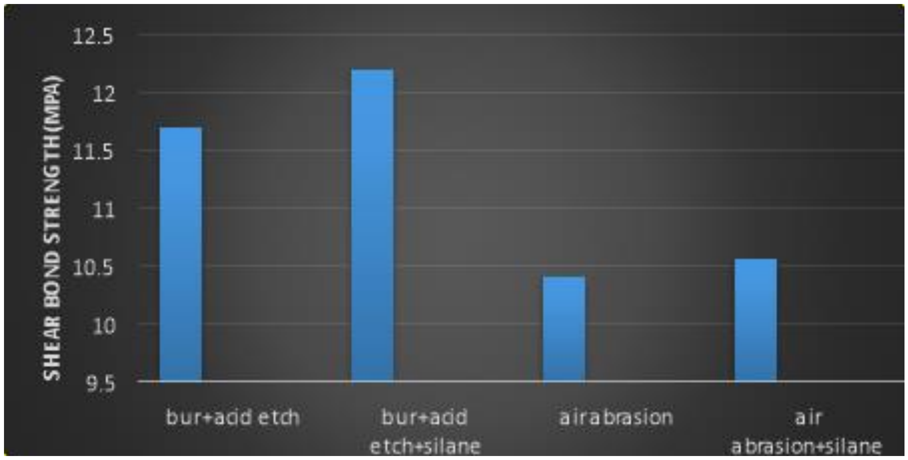


Figure 2 95% confidence interval mean shear bond strength of the brackets bonded to composite surfaces for the Silorane based composite (Filtek P-90) surfaces after preparation with different methods in MPa.

Table 3 frequency of different ARI indexes in the Methylacrylate based composite group (Filtek Z-250) in different preparation methods

Surface Preparation method \ ARI	0	1	2	3	4
Diamond bur + acid etch	0	0	11 (78.6%)	0	3 (21.4%)
Diamond bur + acid etch + Silane	0	0	10 (71.4%)	2 (14.3%)	2 (14.3%)
Air abrasion	0	0	10 (71.4%)	1 (7.1%)	3 (21.4%)
Air abrasion + silane	0	2 (14.3%)	10 (71.4%)	2 (14.3%)	0

(P=0.34)
Grade Zero: Lack of adhesive and resin on the composite surface
Grade 1: Less than 50% adhesive and resin residue on the composite surface
Grade 2: More than 50% adhesive and resin residue on the composite surface
Grade 3: 100% adhesive and resin residue on the composite surface
Grade 4: Restoration Failure

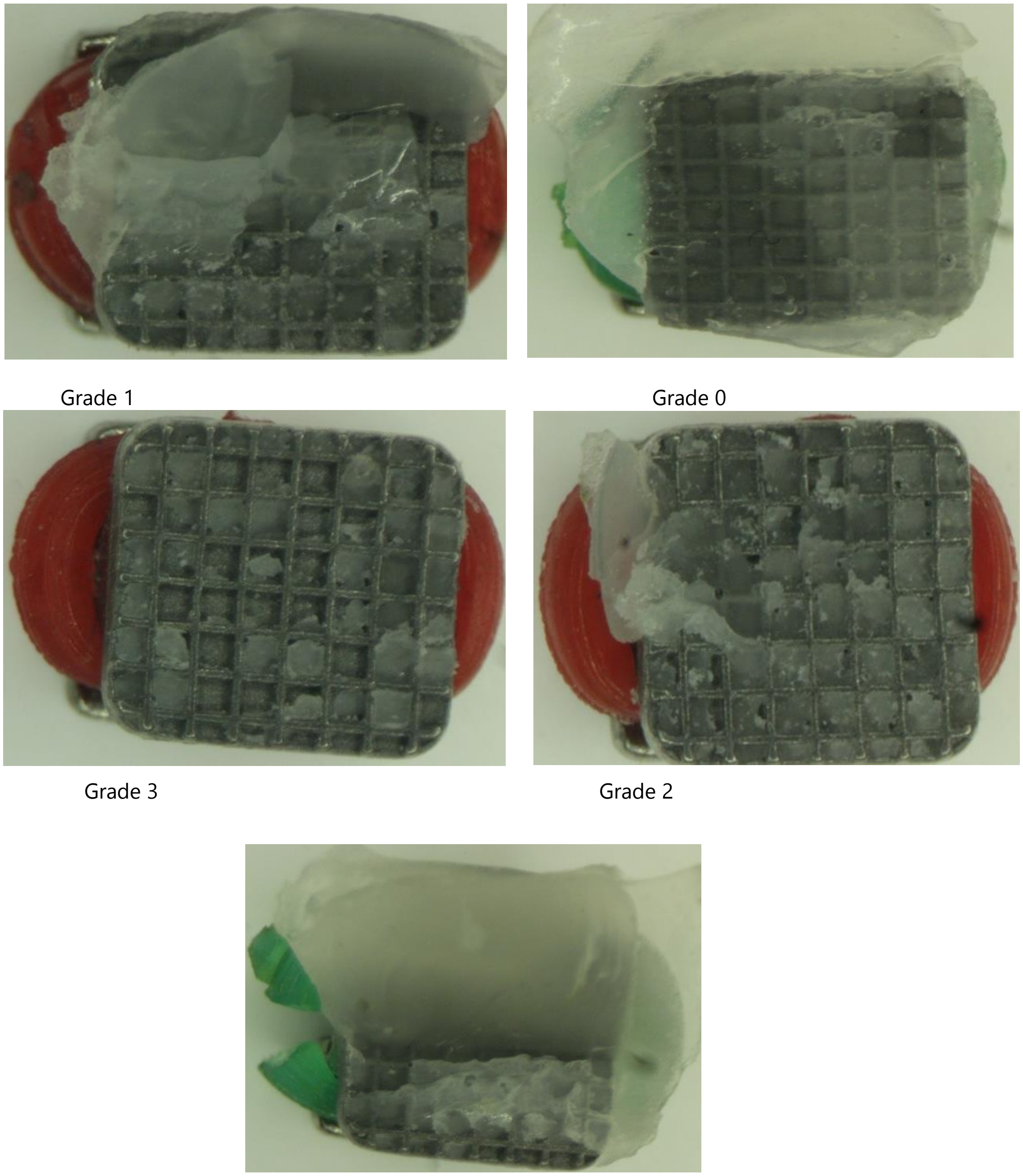
Table 4 frequency of different ARI indexes in the Silorane based composite (Filtek P-90) in different preparation methods

Surface Preparation method \ ARI	0	1	2	3
Diamond bur + acid etch	0	10 (71.4%)	2 (14.3%)	2 (14.3%)
Diamond bur + acid etch + Silane	10 (71.4%)	2 (14.3%)	2 (14.3%)	0
Air abrasion	6 (42.9%)	6 (42.9%)	2 (14.3%)	0
Air abrasion + silane	7 (50%)	4 (28.6%)	3 (21.4%)	0

(P<0.008)

Grade Zero: Lack of adhesive and resin on the composite surface
Grade 1: Less than 50% adhesive and resin residue on the composite surface
Grade 2: More than 50% adhesive and resin residue on the composite surface
Grade 3: 100% adhesive and resin residue on the composite surface
Grade 4: Restoration Failure

Images of adhesive on the composite surface for Grade 1 to Grade 4 have been shown in figure (3).



Grade 1 Grade 0

Grade 3 Grade 2

Grade 4

Figure 3 adhesive remnant(ARI) index

4. DISCUSSION

In this research, the shear bond strength of the metallic orthodontic brackets to methacrylate and Silorane based composite surfaces was evaluated following different preparation methods, and the ARI index was obtained in two groups after debonding the brackets.

There is evidence that gradual reductions in the bond strengths between composites of new and old resins occur after the aging process or remaining in saliva (Chiba et al., 1989; Kao et al., 1988). Therefore, the bond strength between the orthodontic brackets and composite restoration should be high enough to resist bite forces during the treatment course. Bond strength values; Are in relation with variables such as thermal cycling techniques, bond strength measurement tools, place of force applied to debond the brackets, blade tip speed, type of bracket, standardization or non-standardization of contamination or moisture conditions, quality, quantity and variety of materials and methods (Germec et al., 2009). According to Reynolds et al. (1975), the bond strength of orthodontic brackets in clinical conditions should be within the range of 8.7-9.5 MPa (Reynolds, 1975). According to the results of this study, the mean shear bond strength of the brackets to the composite surfaces in a methacrylate based composite (Filtek Z-250) and for the preparation methods including diamond bur cutting + acid etching, diamond bur cutting + acid etching + silane, air abrasion and air abrasion + silane, is equal to 16.36, 13.11, 12.74 and 13.16 Mpa, respectively, and for the Silorane based composite (Filtek P-90) with the same preparation methods, it is equal to 11.7, 8.2, 10.41 and 10.56 Mpa, respectively, indicating that it exceeds the specified range in all cases.

Uysal et al. (2011) investigated the shear bond strength in conventional composites and low-shrink composites (Silorane) when used as an adhesive in lingual retainers, and reported that Silorane composites show an acceptable shear bond strength on the etched enamel surface when used as lingual retainer composite (Uysal et al., 2011). In this study, the mean shear bond strength to the composite surfaces is reported to be 13.84 MPa in the Filtek Z-250 (methacrylate) composite and 10.22 MPa in the Filtek P-90 (Silorane) composite; which is consistent with the findings of this study. Brauchli et al. (2013) evaluated the shear bond strengths of a Silorane-based adhesive in bonding of orthodontic brackets to bovine enamel without preparation, and showed that a Silorane-based composite has poor adhesion to non-prepared enamel in self-etching primers and during conventional etching (In the range of 28.4-87.0 MPa) and this composite was not suitable for bonding the orthodontic brackets to the uncoated enamel (Brauchli et al., 2013). However, in the present study, the bond strengths of the orthodontic brackets to the Silorane composite were greater (within the range of 2.7-8.11 Mega pascal in various preparation methods), which may be due to the lack of preparation of the bovine enamel surface in the above research and other different conditions of that research.

In the present study, the mean shear bond strength to composite surfaces in the Filtek Z-250 (methacrylate) composite was 84.13 MPa and 22.10 MPa in the Filtek P-90 composite (Silorane), which showed that the bond strength of the metal brackets to the methacrylate based composite surfaces is clearly more than the Silorane based composite. Cantekin and Buyuk (2014), reported that the strength of the orthodontic bracket bonding with methacrylate composites is much higher than that of Silorane composites, which is consistent with the present study (Cantekin and Buyuk, 2014). Various methods are available to improve the bond between orthodontic brackets and the composite restorations available in the tooth. These methods include the formation of surface roughness on resin composites by diamond bur cutting or air abrasion, or the application of bonding resins or adhesion facilitators. In some cases, it has been determined that the bond strength between orthodontic brackets and resin composite on the tooth surface increases with the use of diamond bur cutting or the air abrasion process (Bayram et al., 2011; Eslamian et al., 2011; Bishara et al., 2003). Also, acid etching with agents such as phosphoric acid is a common method for preparing dental and composite surfaces. Improvement of bonding after treatment using acid etching can be related to the low surface tension of liquid during which the liquid rapidly flows into irregular surface areas and increases the bond strengths. Also, when using the micro-etcher (air abrasion) system, the eyes, nose and throats should be protected to prevent tissue excitation due to powder particles (Eslamian et al., 2011). According to the results of this study, there were no significant differences in the shear bond strengths of metal brackets to Filtek Z-250 composite surfaces in different preparation methods; however, in composite surfaces with Silorane base (Filtek P-90), the preparation method of diamond bur cutting + etching with phosphoric acid 37% (average of 11.7 mA) produced more shear bond strength compared to the diamond bur cutting process + 37% phosphoric acid + silane application (average of 8.2 MPa), and in other cases, there was no significant difference between the two groups. Considering no significant difference in bond strengths of different preparation methods, the use of less costly methods such as diamond bur cutting or acid etching that require no special clinical consideration seems logical.

In research by Ribeiro et al. (2013) on bovine incisor teeth, the best way to bond orthodontic brackets to composite resin restorations was reported to be surface carving by diamond bur cutting (Ribeiro et al., 2013). However, in the present study, both composite groups use diamond bur cutting + phosphoric acid 37% etching was the best surface preparation method. Bayram et al. (2011); investigated the effect of different preparation methods on shear bond strength of metal brackets to old resin composite surfaces in laboratory conditions and reported the highest bond strength in diamond cutting group (61.10 MPa) and wear with aluminum trioxide (29.10 MPa) (Bayram et al., 2011). According to the results of this study, wearing with 50-micron alumina particles in both groups of composite surfaces with methacrylate base (74.21 MPa) and Silorane (41.10 MPa) produced sufficient amounts of orthodontic bracket bond strength.

The ARI system was proposed by Artun and Bergland (1984) to standardize bonding failure analysis (Artun and Bergland, 1984). According to O'Brien et al. (1988); ARI grades depend on several factors such as base bracket design and adhesive type, and only the bond strengths in the intermediate regions are not effective in this area (O'Brien et al., 1988). On the other hand, t ARI degrees are visually determined, and this issue, along with the different conditions of strength tests, can influence the results of the research. The amount of residual adhesive in various studies is evaluated based on the ARI (Adhesive Remnant Index). The use of this index facilitates the evaluation of defective surfaces, and only a few different indices can be estimated based on the amount of residue remaining in the surface (Reynolds, 1975).

According to various research results, in order to prevent failure or cracking of the enamel surface, resin residuals are to remain on dental surfaces after debonding of the brackets. Of course, the removal of adhesive from dental surfaces after debonding can be difficult and time-consuming and at the same time may lead to damage to the enamel (Reynolds, 1975). In the present study, after debonding of metal brackets from the Filtek Z-250 composite surfaces; significant amounts of adhesive remain on the composite in all of the preparation methods. More than 70% of the samples had ARI 2 Index (more than 50% of adhesive residue), and a significant number of them experienced a repair failure. On the other hand, there were no zero indices (no adhesive residue on the composite). In composite surfaces with Silorane base and in all preparation methods (except for diamond bur cutting + acid etching), in most of the samples, no adhesives remained on the surfaces or less than 50% of adhesives remained on the surfaces (Index 1). Also, there was no evidence of repair failure at these levels, except for diamond bur cutting + acid etching; in other methods, no sample showed index 3. Reducing the amount of residual adhesive on the composite or enamel surfaces is clinically desirable, since less cleaning will be required in this case (Jost-Brinkmann et al., 1996). On this basis, the removal of adhesive residues on the Silorane composite surfaces would be much easier than methacrylate based composites. In other words, orthodontic bracket debonding of Silorane composite is easier than methacrylate composite, and probably causes less damage to the restorative surface.

In previous studies, deflection of metal brackets occurs most often in the bracket-adhesive intermediate region (Uysal et al., 2004; Park et al., 2009; Ostertag et al., 1991; Odegaard & Segner, 1988; Waheed and Kafaei, 2018; Rahman and Vaheed, 2018). Buyuk et al. (2013) found that Silorane-based composites were not debonded into bracket base, same as traditional orthodontic composites, (Buyuk et al., 2013). Brauchli et al. (2013) evaluated the shear bond strengths of a Silorane-based adhesive to orthodontic brackets and non-prepared bovine enamel. Fracture occurred in all Filtek Silorane specimens in the joint between enamel adhesive (Brauchli et al., 2013). These results were partially found in the present study, and in most of the composite samples with Silorane base, the index of residue adhesive was zero. According to the results of this study, although the shear bond strength of the metal brackets to the Silorane base surfaces was somewhat less than the composite surfaces with methacrylate base due to their presence in the acceptable range and the small amount of residue adhesive index after debonding the brackets; Bonding of metal brackets to composite surfaces with a Silorane base was acceptable. On the other hand, all the methods for preparing composite surfaces produced sufficient bond strengths to the composite. However, there is a need for further research in this regard.

5. CONCLUSION

There was sufficient bond strength in all groups studied. The bond strength of the orthodontic brackets in the methacrylate group was higher than the Silorane group for all surface preparation methods and this difference was significant ($p < 0.001$). Despite the lower bond strength of metal brackets to composite surfaces with Silorane base compared to conventional composites, due to their placement in the acceptable range and the small amount of residue adhesive index after the debonding of brackets, bonding of metal brackets to the surfaces of tooth restored with Silorane based composite was acceptable in all composite preparation methods ($p < 0.02$). There was no significant difference in the ARI scores in the preparing methods for composite surfaces with methacrylate base ($p = 0.34$) but these differences were significant in the composite surfaces with Silorane base ($p < 0.008$).

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Conflict of Interest

The authors of this study have declared no conflict of interest.

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