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A comparative study of shear bond strength between metal and ceramic brackets and artificially aged composite restorations using different surface treatments

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SUMMARY This *in vitro* study evaluated the shear bond strength (SBS) between ceramic brackets (CBs) and resin composite restorations (RCRs) prepared using different surface treatments. The findings were also compared with a similar study that used stainless steel brackets (SSBs). Forty-five premolars were restored with a nano-hybrid composite resin (Tetric EvoCeram) and randomly assigned to three surface treatment groups: group 1, 5 per cent hydrofluoric acid (HF); group 2, air abrasion (50 μm alumina particles); and group 3, diamond bur. Specimens were bonded with CBs (Fascination) and exposed to thermo-cycling (500 cycles). The shear force at a crosshead speed of 1 mm/minute was transmitted to brackets. The adhesive remnant index (ARIs) scores were recorded after bracket failure. The analysis of SBS variance ($P < 0.01$) and chi-square test of ARIs scores ($P < 0.01$) revealed significant differences among three groups tested. The SBS in group 3 (mean: 26.34 ± 4.76 MPa) and group 2 (mean: 26.68 ± 5.93 MPa) was significantly higher than group 1 (mean: 16.25 ± 5.42 MPa). The SBS was significantly higher in CBs (mean: 23.09 ± 7.19 MPa) compared to SSBs (mean: 15.56 ± 5.13 MPa). High ARIs (100 per cent) occurred in SSBs treated with a diamond bur, whereas CBs primarily failed at the resin–adhesive interface ($P < 0.01$). In two-thirds of the specimens (SSBs or CBs), no adhesive was left on the restoration after HF conditioning. The ARIs profile of CBs and SSBs that received surface treatments with air abrasion were similar ($P > 0.05$) and bond failure occurred mainly in adhesive–bracket base and resin–adhesive interfaces. The diamond bur surface treatment is recommended as a safe and cost-effective method of bonding CBs to RCRs.

Introduction

Ceramic brackets (CBs) were introduced to the market in the mid-1980s to address the increasing aesthetic demands of orthodontic patients (Birnie, 1990; Verstrynge *et al.*, 2004). These are made of aluminum oxides, which have many advantages such as biocompatibility, good aesthetics, and resistance to temperature and chemical changes (Harris *et al.*, 1992; Karamouzos *et al.*, 1997). There are two types of CBs: polycrystalline and monocrystalline alumina CBs (Bordeaux *et al.*, 1994; Bishara and Fehr, 1997; Gautam and Valiathan, 2007). The bond strength between CBs and enamel is usually higher or equal to that of stainless steel brackets (SSBs) (Odegaard and Segner, 1988; Swartz, 1988; Flores *et al.*, 1990; Viazis *et al.*, 1990). However, the higher bond strength between CBs and enamel can theoretically increase the risk of irreversible damages to the enamel. Taken as a whole, the higher bond strength and the lack of ductility are the main problems associated with CBs. The resistance to deformation can cause stress build-up in the enamel–adhesive interface during the bracket removal, increasing the risk of enamel cracks and tear-outs (Swartz, 1988; Bishara and Trulove, 1990; Jerioudi, 1991; Bishara *et al.*, 1993; Tocchio *et al.*, 1993; Verstrynge *et al.*, 2004). The debonding forces can also fracture the CB or the adhesive system at the tooth or resin surface. This can lead to cracks in the susceptible enamel (Bishara, 2000).

In an attempt to address the higher bond strength between the CBs and tooth, clinicians decreased the etching time from 30 to 10 seconds (Olsen *et al.*, 1996). However, several other methods are also available to reduce the bond strength. These methods all aimed at easing the debonding process and include the application of a fine layer of polymers to the bracket base (Franklin and Garcia-Godoy, 1993), the use of brackets with predetermined lines of fracture (Verstrynge *et al.*, 2004), the use of self-etching primer (Uysal *et al.*, 2010a), the use of amorphous calcium phosphate-containing orthodontic composite (Uysal *et al.*, 2010b), the use of ultrasonic instruments (Krell *et al.*, 1993), the application of electrothermal devices (Sheridan *et al.*, 1986a,b; Bishara and Trulove, 1990; Sernetz and Kraut, 1991), and finally the use of lasers to degrade and soften adhesives (Feldon *et al.*, 2010; Iijima *et al.*, 2010; Nalbantgil *et al.*, 2010; Oztoprak *et al.*, 2010; Sarp and Gülsoy, 2010; Tehranchi *et al.*, 2010). Lately, clinicians are more likely to place orthodontic appliances on teeth restored with resin composite restorations (RCRs) or resin laminate veneers. This is associated with two major concerns. Firstly, the bond strength should be strong enough to withstand the forces applied during the orthodontic treatment. Secondly, the generated bond strength should not be too strong; otherwise damages to the RCRs during the debonding process would be expected. This imposes unnecessary costs to the patient. However, the orthodontist's major concern should be to preserve the integrity of the RCR.

Achieving a reliable bond strength between brackets and RCRs is an utmost concern of orthodontists. Several methods have been suggested to address this concern, such as increasing the etching time with phosphoric acid to 30–60 seconds (Kao *et al.*, 1995; Chunhacheevachaloke and Tyas, 1997; Lai *et al.*, 1999; Viwattanatipa *et al.*, 2010), sandblasting (Bishara *et al.*, 2003; Viwattanatipa *et al.*, 2010), and surface roughening with tungsten carbide (Bishara *et al.*, 2003) or diamond burs (Schwartz *et al.*, 1990; Viwattanatipa *et al.*, 2010; Eslamian *et al.*, 2011). The chemical approaches were also used by using hydrofluoric acid (HF) surface etching (Viwattanatipa *et al.*, 2008; Viwattanatipa *et al.*, 2010), the application of silane (Newman *et al.*, 1984; Kao *et al.*, 1995; Bishara *et al.*, 2003; Viwattanatipa *et al.*, 2008; Eslamian *et al.*, 2009), and the use of bonding agents (Schwartz *et al.*, 1990). However, the challenging issue is whether previous findings can be applied to CBs. These studies used different bracket types (i.e. stainless steel or ceramic) and materials (i.e. composite cylinders, bovine or human teeth), various preparation methods (i.e. different etching times and concentrations with phosphoric acid or HF, different air abrasion systems), and different methodologies [i.e. survival probability or shear bond strength (SBS) analysis]. Therefore, the primary objective of the present study was to evaluate the SBS between CBs and RCRs that received different surface treatments. The secondary aim of the study was to compare the present findings with a similar study, which used the SSBs (Eslamian *et al.*, 2011). For the first part of this study, the null hypothesis presumed that there were statistically significant differences between SBS values and bond failure sites of CBs bonded to RCRs prepared using different surface treatment methods. For the second part of this study, the null hypothesis was that there was a statistically significant difference between average SBS values in CBs and SSBs bonded to RCRs prepared using different surface treatment methods.

Materials and methods

Specimen preparation

Forty-five recently extracted non-carious human premolars with sound buccal surfaces were selected. The teeth were cleaned, lightly pumiced, and stored in distilled water at room temperature before use. A 6 mm diameter by 1 mm depth cavity was cut in the buccal surface of each tooth with a fissure bur and etched with 37 per cent phosphoric acid solution for 30 seconds. The cavities were then rinsed, dried with a blast of air, and a thin layer of Heliobond bonding resin (Ivoclar Vivadent Technical, Schaan, Liechtenstein) applied to the base of the cavity before filling it with the nano-hybrid resin-based composite, the Tetric EvoCeram (Ivoclar Vivadent Technical). The composition and properties of Tetric EvoCeram are given in Table 1. The restorations were shaped with diamond burs and sandpaper discs and polished with rubber cups and paste. All specimens were stored in deionized water for 1 week at room temperature and randomly assigned to three equal groups:

Group 1. The buccal surface was etched for 60 seconds with 5 per cent HF (Ivoclar Vivadent Technical) at room temperature, rinsed for 60 seconds with water, and dried with a blast of air.

Group 2. The buccal surface was air abraded with a micro etcher (Danville Engineering Incorporated, Danville, California, USA) using 50 μm alumina particles for 7 seconds at a 90 degree angle. The cleaning and drying procedures described in group 1 were applied.

Group 3. The buccal surface was roughened with a diamond bur with grit sizes 125–150 μm (863 Grit; Drendell and Zweilling, Berlin, Germany) rotating at high speed with

Table 1 The standard composition and selected physical properties of Tetric EvoCeram according to the manufacturer.

Standard composition (%)	
Dimethacrylates	16.8
Barium glass filler, Ytterbium trifluoride, and mixed oxide	48.5
Prepolymers	34
Additives, stabilizers, and catalysts	0.7
Pigments	<0.1
Selected physical properties (MPa)	
Flexural strength	120
Modulus of elasticity	10000
Compressive strength	250

a constant water spray. A rotating bur passed over the composite surface three times. The cleaning and drying procedures described in group 1 were applied.

Ceramic brackets

For this experiment, the Fascination CBs were used (Fascination; Dentaurum, Ispringen, Germany). They were bonded to the composite restorations with a no-mix adhesive resin (Resilience; Confi-Dental Products Company, Louisville, Colorado, USA). According to the manufacturer, the Fascination ceramic orthodontic brackets are made of polycrystalline aluminum oxide and they do not have the predetermined fracture line or vertical grooves (i.e. to ease the debonding processes). They also have a silane coating that allows for easy debonding. The bonding surface of the brackets has nub-like structures, which are coated with a silane layer. According to the manufacturer, the silane layer should not be touched or contaminated otherwise it affects the adhesion adversely. Thus, the operator wore gloves during the bracket placement process. A thin layer of adhesive primer was applied to the buccal surfaces of the restorations. The adhesive resin paste was applied to the bracket base and the bracket seated on the surface of the restoration with a force of approximately 5 N. The excess adhesive resin was removed with an explorer before polymerization with a curing light. All the specimens were cycled 500 times between 5°C and 55°C with a dwell time of 30 seconds between each cycle. To facilitate debonding, the teeth were mounted in acrylic resin (Orthoresin, De Trey; Dentsply, Weybridge, UK) with the buccal surfaces parallel to the debonding blade.

SBS testing

The shear bond test was performed with a universal testing machine (Z020; Zwick GmbH, Ulm, Germany). The shear force at a crosshead speed of 1 mm/minute was transmitted to the bracket and the teeth were aligned so that the applied force was perpendicular to the bracket. The force required to shear the bracket was recorded and the bond strength was calculated in megapascals (MPa). The findings of this study was compared with the recommended bond strength of 5.9–7.8 MPa suggested by Reynolds (1975).

Adhesive remnant index

The sheared surfaces were further investigated with a stereomicroscope (Olympus, SZX9, Tokyo, Japan) at ×20 magnification to assess the adhesive remnants on the specimen surface. The adhesive remnant index (ARI) as described by Artun and Bergland (1984) was used and recorded for this assessment. ARI scores were used as a means of defining the sites of bond failure between the enamel, resin (adhesive), and the bracket base. The ARI (the substrate ARI score or ARIs) was scored 0–3, as follows:

0, no adhesive left on the tooth
1, less than half of the adhesive left on the tooth
2, more than half of the adhesive left on the tooth
3, all the adhesive left on the tooth with the mesh pattern visible

Comparison with SSBs

As mentioned earlier, Eslamian *et al.* (2011) previously conducted an experiment with SSBs with a similar laboratory setup. We compared the SBS and ARIs data of the present investigation with this study (Eslamian *et al.*, 2011) that was aimed at assessing the effect of different surface treatments on SBS between SSBs and RCRs.

Statistical analysis

Statistical analysis was performed with SPSS software, Version 17.0 (Statistical Package for Social Sciences; SPSS Inc., Chicago, Illinois, USA). To assess the SBS, descriptive statistics such as means, medians, and standard derivations were calculated in the data analysis. The SBS between ceramic and RCR for three different surface treatments was subjected to one-way analysis of variance (ANOVA). The chi-square test was also used to evaluate differences in the ARIs scores among the groups and between every two group.

As mentioned earlier, the current data for SBS between CBs and RCRs were compared with a similar study that assessed the effect of different surface treatments on SBS between SSBs and RCRs (Eslamian *et al.*, 2011). In this process, one-way ANOVA was used to assess the effect of different surface treatments on SBS between SSBs/CBs and RCRs. The chi-square test was also used to evaluate differences in the ARIs scores between the groups (ceramic and stainless steel). Box plots were also used to show the SBS data graphically. The level of significance for the present study was set at 0.05 ($P < 0.05$).

Results

SBS and ARI in CBs

Shear bond strength. The mean SBS between RCRs and CBs was 23.09 ± 7.19 (SD) MPa, regardless of the surface treatments applied. The descriptive statistics for SBSs of the three surface treatment groups are shown in Table 2. The mean SBS ranged from 16.25 MPa (HF group) to 26.68 MPa (air abrasion group).

ANOVA analysis showed significant differences among three surface treatment groups for CBs ($F = 18.13$, $P = 0.00$). Compared to CBs that bonded to specimens with HF surface treatment [16.25 ± 5.42 MPa, 95 per cent confidence interval (CI) 13.25–19.25], a significantly higher SBSs were observed in CBs received surface treatment with a diamond bur (26.34 ± 4.76 MPa, 95 per cent CI, 23.70–28.98) and air abrasion (26.68 ± 5.93 MPa, 95 per cent CI, 23.39–29.96). The average SBS difference between the HF group and diamond bur/air abrasion groups were 10.09 (P = 0.00, 95 per cent CI, 5.30–14.87) and 10.43 MPa (P = 0.00, 95 per cent CI, 5.64–15.21), respectively. The mean SBS was not significantly different between the CBs that received surface treatment with a diamond bur or air abrasion (P = 0.98, mean SBS difference = 0.34 MPa, 95 CI, −5.12 to 4.44). Therefore, the null hypothesis was partially rejected for the first part of the study that assessed the SBS between CBs and RCRs.

Adhesive remnant index. The amount of residual adhesive on the RCRs surface as evaluated by the ARIs scores is shown in Tables 3. The chi-square test revealed significant differences among CBs in three surface treatment groups (chi-square = 39.53, df = 6, P = 0.00). The specimens that received HF surface treatment showed ARIs scores of 0 (73.3 per cent) and 1 (26.7 per cent), showing that none or slight amount of composite remained on the RCR surface. The ARIs scores of specimens in air abrasion and diamond bur groups were mainly 1 and 2 (12/15 and 15/15, respectively), indicating that a significant amount of composite remained attached to the RCR surfaces after the bracket failure. Therefore, the null hypothesis was not rejected for the first part of the study that compared the bond failure sites between CBs and RCRs.

Table 2 The descriptive statistics of shear bond strengths (megapascal) in different groups (each group consisted of 15 specimens).

Group	Mean (SD)	Median	Range
Hydrofluoric acid	16.25 (5.41)	17.01	8.67–27.56
Air abrasion	26.68 (5.93)	25.15	18.29–36.71
Diamond bur	26.34 (4.75)	27.80	18.88–35.20

Comparison of CBs with SSBs

Figure 1 shows the box plots on SBS among CBs/SSBs and RCRs with their corresponding surface treatment. The CBs produced significantly higher SBS (23.09 ± 7.19 MPa) in comparison with SSBs (15.56 ± 5.13 MPa), regardless of the surface treatments they received (P < 0.01). Therefore, the null hypothesis for the second part of the study was not rejected. The ANOVA showed that there were significant differences among six groups tested (F = 20.11, P = 0.00). The CBs in diamond bur and air abrasion groups produced the highest mean SBS with RCRs. The stainless steel group treated with HF showed the lowest mean SBS, followed by ceramic group treated with HF. However, the mean SBS difference between these two groups was not statistically significant (Figure 1). The largest SBS difference was found between the CBs in the air abrasion group and the SSBs in the HF group (mean SBS difference 13.82 MPa).

The differences in ARIs scores among ceramic (CBs) and SSBs groups were significant (chi-square = 108.38, df = 15, P = 0.00; Table 4). The SSBs that received surface treatment with a diamond bur consistently failed at the resin–bracket base interface, whereas CBs primarily failed at the resin–adhesive interface (chi-square = 26.67, P = 0.00). Nearly two-thirds of CBs and SSBs that received HF surface treatment showed failure at the resin–adhesive interface, although the failure profile was different (chi-square = 9.04, P = 0.029). There was no significant difference between CBs and SSBs groups treated with air abrasion and bond failure occurred mainly in resin–bracket base and resin–adhesive interfaces (chi-square = 0.71, P = 0.70).

Table 3 The adhesive remnant index scores on resin composite restoration surfaces (ARIs) with different surface treatment methods.

	Surface treatment	N	ARIs			
			0	1	2	3
CBs	HF	15	11 (73.3)	4 (26.7)	0	0
	Air abrasion	15	0	4 (26.7)	8 (53.3)	3 (20)
	Diamond bur	15	0	10 (66.7)	5 (33.3)	0
	Total	45	11 (24.4)	18 (40)	13 (28.9)	3 (6.7)
Chi-square = 39.53, df = 6, P = 0.00						

First group (n = 15)	Second group (n = 15)	df	$\chi 2$	P value
CB + HF	CB + air abrasion	3	17.61	0.001
CB + HF	CB + diamond bur	2	18.57	0.000
CB + air abrasion	CB + diamond bur	2	6.26	0.044

CB, ceramic brackets; HF, hydrofluoric acid. The second part shows the result of chi-square test between ceramic bracket groups.

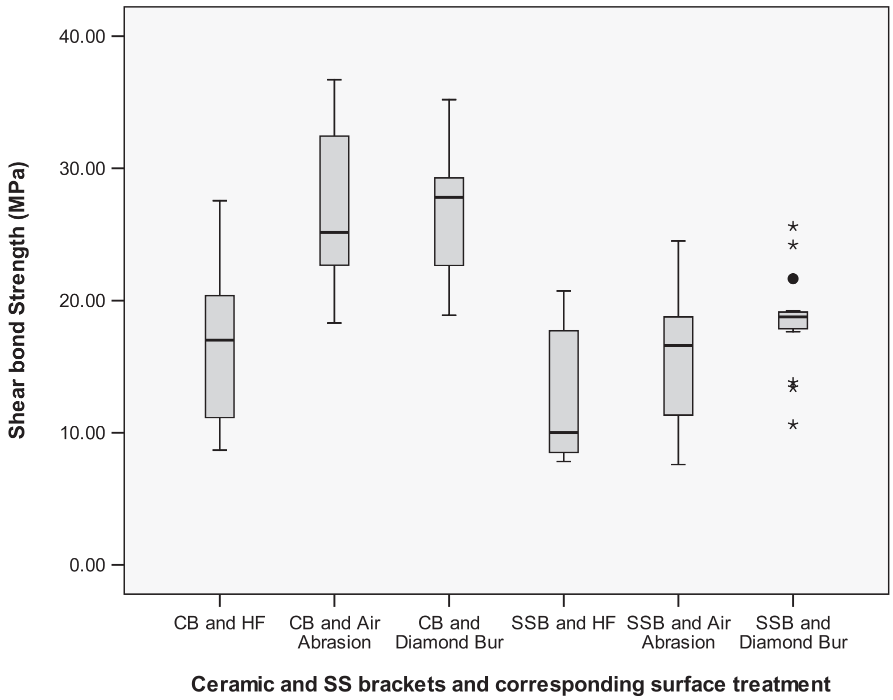

Figure 1 The box plots showing the shear bond strength for ceramic brackets (CB) and stainless steel rackets (SSB) bonded to resin composite restoration surfaces and their corresponding surface treatment (Eslamian *et al.*, 2011).

Table 4 The adhesive remnant index (ARIs) scores on resin composite restoration surfaces for ceramic and stainless steel brackets (Eslamian *et al.*, 2011) with the corresponding surface treatment methods.

Experiment groups	ARIs				Total	
	0	1	2	3		
HF ceramic brackets	11	4	0	0	15	
HF stainless steel brackets	10	0	1	4	15	Chi-square = 9.04, d*f* = 3, *P* = 0.029
AA ceramic brackets	0	4	8	3	15	
AA stainless steel brackets	0	3	7	5	15	Chi-square = 0.710, d*f* = 3, *P* = 0.70
DB ceramic brackets	0	10	5	0	15	
DB stainless steel brackets	0	0	1	14	15	Chi-square = 26.67, d*f* = 3, *P* = 0.00
Total	21	21	22	26	90	

AA, air abrasion; DB, diamond bur; HF, hydrofluoric acid. All groups: chi-square = 108.38, d*f* = 15, *P* = 0.00.

Discussion

The present study assessed the effect of different surface treatments on SBS between CBs and RCRs. We also compared our findings with a similar study that used SSBs (Eslamian *et al.*, 2011). The increase in mechanical interlocking is the most significant factor that contributed to bond strength between composite resins (Brosh *et al.*, 1997). Traditionally, a 37 per cent orthophosphoric acid is used for conditioning the enamel surface. However, it appears that 37 per cent orthophosphoric acid is not capable of changing the surface morphology of composite resins and merely cleans the composite resin surfaces (Jordan, 1993; Viwattanatipa *et al.*, 2010). The air abrasion procedures were originally introduced to the dental profession to clean or roughen various surfaces (Goldstein and Parkins, 1994). Subsequently, it was used to condition the enamel surface for the bonding purposes (Gerbo *et al.*, 1993; Goldstein and Parkins, 1994). The advantage of using air abrasion is the controlled removal of enamel during enamel surface preparation. However, the loss of both organic and inorganic components when air abrasion is used results in an irreversible loss of enamel.

In the present study air abrasion and surface roughening with a diamond bur equally produced the highest SBS in CBs and also the highest average SBS in comparison with SSBs. According to our findings, air abrasion produced one of the highest SBSs that were much higher than the recommended 5.9–7.8 MPa by Reynolds (1975). This is contrary to its use in enamel that produced significantly lower bond strengths compared to the enamel conditioning with 37 per cent phosphoric acid (Olsen *et al.*, 1997). In the present study, the average SBS values ranged between 12.85 MPa (i.e. SSBs bonded to RCRs with HF surface treatment) and 26.68 MPa (i.e. CBs bonded to RCRs with air abrasion surface treatment). However, previous studies reported a much wider range of SBS values. For instance, Viwattanatipa *et al.* (2010) used the disc model and SSBs. They reported much lower values between 4 MPa (conditioning with 9.6 per cent HF for 2 minutes) and 6.9 MPa (sandblasting with 90 μm alumina particles). Lai *et al.* (1999) compared the SBS of metal, ceramic, and polycarbonate brackets bonded to unconditioned microfilled resin composite. They reported mean SBSs in the range of 17.2–24.9 MPa. Similarly, Schwartz *et al.* (1990) and Eslamian *et al.* (2009) reported average SBS values between 10.3 to 10.5 and 13.1 to 19.4 MPa, respectively. These differences in bond strength values may be due to different methodologies they used or the use of different composite resin and surface treatments.

The ARIs scores were used as a more detailed means of evaluating the bond failures location in three surface treatment groups. We found a significantly lower SBS in CCBs that received HF conditioning compared with groups that received surface treatment with air abrasion or diamond bur. However, in the previous study that used SSBs (Eslamian *et al.*, 2011), there was no significant difference between the HF conditioning and air abrasion groups. The CBs prepared with the HF showed ARIs scores of 0 (73.3 per cent) and 1 (26.7 per cent), indicating that none or slight amount of composite remained on the RCRs surfaces. This shows that bond strength between the CB base and adhesive was much stronger than that between the adhesive and the RCRs. In contrast, in the air abrasion and diamond bur groups ARIs scores were mainly 1 and 2 (12/15 and 15/15, respectively). This shows that a significant amount of adhesive remained attached to the surface of RCRs.

In the present study, CBs produced a significantly higher mean SBS with RCRs (23.09 ± 7.19 MPa) compared to SSBs (15.56 ± 5.13 MPa). Similar trends were observed when bonding SSBs and CBs to the enamel (Odegaard and Segner, 1988; Swartz, 1988; Flores *et al.*, 1990; Viazis *et al.*, 1990). The differences in ARIs scores among CBs and SSBs also reached significance. In sound teeth, bond failure at the bracket–resin interface or within the resin (adhesive) is more desirable than at the resin–enamel interface. This is due to enamel fracture and cracking that may occur during bracket debonding, particularly with CBs (Bishara *et al.*, 1997). The surface characteristics of enamel and RCRs are distinct, and consequently, the bond mechanism is different. In the enamel, this is mainly the mechanical retention that holds the brackets on the surface. However, in RCRs, the chemical retention may play a more prevailing rule. At this point in time, there is a lack of information regarding the desirable form of bond failure between CBs/SSBs and RCRs. We know that SSBs consistently fail at the resin–bracket base interface, whereas CBs with chemically retained bases primarily fail at the resin–enamel interface (Joseph and Rossouw, 1990). This can be due to lack of ductility and higher bond strength between CB base and the adhesive. In the present study, we observe a similar trend in CBs and SSBs bonded to RCSs and treated with a diamond bur. This trend was also observed, to a much lesser extent, in the CBs and SSBs that received surface treatment with HF. In fact, similar to bonding to enamel, the ARIs profile for ceramic and SSBs were different in groups that received surface treatment with diamond bur or HF. Surprisingly, the bond failure profile in groups that received surface treatment with air abrasion was similar and independent of bracket type used. The CBS and SSBs that received surface treatment with air abrasion showed bond failure mainly in the resin–bracket base and resin–resin interfaces. While the explanation is unclear, this pattern of bond failure may be attributed to the superior bond strength and more homogenous mechanical retention that air abrasion creates.

The current study only evaluated the SBS and used ARIs to assess the bond failure profile between brackets and RCRs. A possible limitation of the present study is the use of chemically treated CBs (silane). The dissimilar bracket bases, such as those with a mechanical retention only or epoxy-base mechanical retention, may produce a different SBS or ARIs profile between CBs and RCRs. The current study only evaluated the SBS and used ARIs to evaluate the bond failure between brackets and RCRs. The classification system (ARI) that we used, unfortunately, did not allow us to record any damage to the surface of RCRs after the bracket failure. In order to avoid damage to the RCRs, further studies using different bracket types and surface treatment methods with simultaneous use of manufacturer's debonding instructions are needed. These studies should evaluate before and after debonding images. Another possible limitation of the current study is its *in vitro* nature. We know that the average *in vivo* bond strengths are approximately 40 per cent less than those measured in the *in vitro* studies (Hajrassie and Khier, 2007). There is also evidence for a gradual decrease in bond strength between new and old composite due to aging and storage of material in saliva (Boyer *et al.*, 1984; Kao *et al.*, 1988; Chiba *et al.*, 1989). Therefore, most measured *in vivo* bond strengths may not be as high as those measured using the *in vitro* models. Bearing in mind the above discussed limitations, the findings of this study suggest that surface treatment with a diamond bur and air abrasion equally provides the highest SBS between CBs and RCRs. However, there are difficulties associated with the air abrasion usage, and therefore, the use of diamond bur surface treatment as a safe and effective method is recommended.

Conclusions

The surface treatment with a diamond bur and air abrasion equally produced the highest SBS between CBs and RCRs. In ceramic and SSBs, the lowest SBS was observed in the HF-treated groups. All combinations investigated showed clinically acceptable bond strengths with CBs [i.e. higher than 5.9–7.8 MPa suggested by Reynolds (1975)]. In CBs, significant differences were found among the ARIs scores of the three surface treatment groups. The ARIs profile of CBs and SSB groups that received surface treatments with air abrasion were similar, unlike the other two surface treatment methods. The CBs produced significantly higher SBS (23.09 ± 7.19 MPa) compared to SSBs (15.56 ± 5.13 MPa). The greatest SBS difference was observed between the ceramic group treated with air abrasion and the stainless steel group treated with HF. The diamond bur surface treatment was considered a safe and effective method of achieving high SBS in ceramic and SSBs.

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