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Shear bond strength of ceramic brackets bonded to three different porcelain surfaces

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ABSTRACT

Introduction: The aim of this study is to determine the shear bond strength (SBS) of ceramic brackets bonded to three different porcelain surfaces. **Materials and Methods:** A total of 36 porcelain crowns were used in this study. Porcelain crowns were allocated to the three groups as follows: Conventional porcelain-fused-to-metal crowns, IPS e.max ceramic crowns, and porcelain-fused-to-zirconia crowns. Porcelain surfaces were etched with 9.6% hydrofluoric acid and rinsed with a water/spray combination. Then, ceramic brackets were bonded with a light-cured composite resin. All the specimens were stored in distilled water at 37°C for 24 hours and thermocycled and loaded into a universal testing machine for testing. Any adhesive that remained after debonding was assessed and scored according to the modified adhesive remnant index (ARI). **Statistical Analysis:** One-way analysis of variance (ANOVA) and Tukey's test were used to compare the SBS of the groups. The Chi-square test was used to determine the ARI scores among the groups. **Results:** No statistically significant difference between the ARI scores for the three types of crowns was observed. In the conventional porcelain-fused-to-metal crown group (7.09 MPa), the lowest values of bond strength were obtained. Although similar values of bond strength were found in the IPS e.max ceramic crown (8.60 MPa) and porcelain-fused-to-zirconia crown (8.93 MPa) groups, the statistically significant differences in values of shear bond strength have observed between the other groups. **Conclusions:** SBS of ceramic brackets bonded to different porcelain surfaces may produce different results due to the type of porcelain crown.

KEYWORDS: Adhesive remnant index, brackets, porcelain, surface preparation

Introduction

In adults, particularly, clinicians often bond orthodontic brackets to teeth that have different types of restorations, such as porcelain crowns or laminates. Porcelain surfaces do not bond readily with orthodontic brackets; so, the surface characteristics of porcelain or ceramic are altered through certain approaches before bonding the brackets to porcelain.[1,2] Some of these are applying silane coupling agents to the porcelain surface and etching with hydrofluoric acid, or sandblasting the porcelain surface.[3-5]

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Mechanical alteration of the porcelain surface such as sandblasting or air abrasion increase the bond strength but the porcelain glaze is damaged by this method. Another approach used to increase the bond strength of the porcelain surface is chemical alteration by pretreating the surface of the porcelain with silane coupling agents and using hydrofluoric acid to etch the porcelain surface.[1] Phosphoric acid solution is also used to enhance bond strength of the porcelain surface but it is not as efficient as microetching the porcelain surface with the application of hydrofluoric acid and silane coupler.[6-8] Silane coupling agents increase the bond strength of brackets to porcelain,[9,10] but some studies indicate that silane couplers have also effectuated cohesive failure during debonding.[11,12]

Adult patients seeking orthodontic treatment usually prefer transparent brackets such as ceramic brackets for esthetic appearance. Currently, ceramic brackets are made of aluminum oxide.[13,14] Ceramic brackets bond to teeth with mechanical retention between the bracket base and the adhesive resin and by applying silane coupling agents to the porcelain surface.[3,15]

Although these brackets are esthetically advantageous, fractures and cracks maybe seen at the enamel or porcelain surfaces during debonding procedures.[16] Three different debonding methods can be used for preventing damage to the enamel surface. These methods are the conventional method using pliers or wrenches, the ultrasonic method, and the electrothermal method of transmitting heat to the adhesive through the bracket.[17,18] Kocadereli *et al*. reported that when ceramic brackets bonded to porcelain surfaces, no damage occurred on the porcelain restoration surface on macroscopic and microscopic examination.[19] There was no difference found between the damage caused by debonding of stainless steel or ceramic orthodontic brackets.[20]

Ceramic brackets increase the friction to metal brackets. The advantages of the Clarity™ bracket (3M Unitek, Monrovia, California, USA) that has a metal-lined arch wire slot is minimizing the increased friction and strengthening the orthodontic bracket to produce orthodontic torque force.[21]

Our objectives in this study were to evaluate the shear bond strength (SBS) of ceramic brackets bonded to three types of ceramic crown materials.

Materials and Methods

A total of 36 porcelain crowns were used in this study. Porcelain crowns were constructed according to the recommendations of the manufacturer. Three types of ceramic crowns were fabricated by a technician and allocated to one of the three groups as follows: Conventional porcelain-fused-to-metal crowns (Ceramco 3, Dentsply, York, Pennsylvania, USA), IPS e.max ceramic crowns (Ivoclar Vivadent AG, Schaan, Liechtenstein), and porcelain-fused-to-zirconia crowns (Zirkonzahn GmbH, Gais, Italy, Noritake Co., Tokyo, Japan).

Porcelain surfaces were etched with 9.6% hydrofluoric acid (Pulpdent, Watertown, Massachusetts, USA) for two minutes, rinsed with a water/spray combination for 30 seconds, and dried before the application of silane. Silane primer (Ormco Porcelain Primer, Glendora, California, USA) was applied to the etched porcelain surface with a microbrush and allowed to dry for five minutes.

Ceramic brackets (Clarity™, metal-reinforced ceramic bracket, 3M Unitek, Monrovia, California, USA) were bonded with a light-cured composite resin (Light Bond, Reliance Orthodontic Products Inc. Itasca, Illinois, USA). A thin uniform layer of sealant was applied on the etched porcelain surface with a microbrush and cured for 20 seconds. A thin coat of sealant was also painted on the ceramic bracket base and cured for 10 seconds before applying the paste. Using a syringe tip, the paste was applied to the bracket base. The bracket was then positioned on the porcelain tab and pressed lightly. Excess adhesive was removed with a sharp scaler. The specimens were cured with soft-start mode LED (MiniLED™, Satelec, Merignac Cedex, France) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surface of the brackets).

All the specimens were stored in distilled water at 37°C for 24 hours and thermocycled for 500 cycles between 5 and 55°C using a dwell time of 30 seconds. Each specimen was loaded into a universal testing machine using Nexjen software (Nexjen Systems, Charlotte, North Carolina, USA) for testing, with the long axis of the specimen perpendicular to the direction of the applied force. A standard knife edge was positioned to make contact with the bonded specimen. Bond strength was determined in shear mode at a crosshead speed of 0.5 mm/minute until fracture occurred.

After debonding, all teeth and brackets in the test groups were examined under ×10 magnification. Any adhesive remaining after debonding was assessed and scored according to the modified adhesive remnant index (ARI).[12] The scoring criteria of the index are as follows:

1. All of the composite, with an impression of the bracket base, remained on the tooth
2. More than 90% of the composite remained on the tooth
3. More than 10% but less than 90% of the composite remained on the tooth
4. Less than 10% of composite remained on the tooth
5. No composite remained on the tooth.

Statistical analysis

Descriptive statistics including mean, median, standard deviation, and quartiles were calculated for each of the groups tested. One-way analysis of variance (ANOVA) and Tukey's test were used to compare the SBS of the groups. The Chi-square test was used to determine significant differences in the ARI scores among groups. Significance for all statistical tests was predetermined at $P < 0.05$. All analyses were performed with the Statistical Package for Social Sciences version 17.0.0 (SPSS Inc., Chicago, Illinois, USA).

Results

Mean bond strength, standard deviations, and significance for each group are shown in Table 1. Similar bond strength values occurred between IPS e.max ceramic crown (8.60 MPa) and porcelain-fused-to-zirconia crown (8.93 MPa) groups. In the IPS e.max ceramic crown group (8.60 MPa), significantly higher

Table 1: The results of the analysis of variance comparing the shear bond strengths of the groups

IPS e.max	Ceramo-zirconia	Ceramo-metal	Significance	Post hoc tests
Mean SD	Mean SD	Mean SD	**	I-II I-III II-III
8,60 1,03	8,93 1,20	7,09 1,09		ns***

NS = Non significant; *P< .05, **P<. 01, IPS = Ingots for the press technique

Table 2: Frequency distribution of the ARI scores and Chi-square comparison of the groups

Groups	ARI scores					*n*	Test
	1	2	3	4	5		
IPS e.max	2	4	4	1	1	12	ns
Ceramo-zirconia	1	3	5	3	0	12	ns
Ceramo-metal	0	4	5	3	0	12	ns

NS = Non significant, ARI = Adhesive remnant index, IPS = Ingots for the press technique

bond strength values were obtained than in the conventional porcelain-fused-to-metal crown (7.09 MPa) group. Also porcelain-fused-to-zirconia crown group (8.93 MPa) showed significantly higher bond strength values than the conventional porcelain-fused-to-metal crown (7.09 MPa) group.

The data for debonding strength for the three types of ceramic crowns are shown in Table 2. No statistically significant difference between ARI scores for the three types of crowns was observed ($P > 0.05$).

Discussion

Our aim in this study was to determine whether there is a difference in the bond strengths of ceramic brackets bonded to three types of ceramic crown materials.

It has been suggested that the optimal range for bond strength of orthodontic brackets to enamel is 6 to 10 MPa.[22] Hydrofluoric acid has a higher tensile bond strength that is used for increasing bond strength of brackets to porcelain teeth. When hydrofluoric acid is compared with sandblasting using aluminum trioxide, there was minimal damage on the porcelain surface during porcelain bonding. Sandblasting with aluminum trioxide is not preferred as a conditioning technique for enhancing bond strength to the porcelain surface because of its lower bond strength effect.[23,24] It was reported that ceramic might be etched with hydrofluoric acid to prevent ceramic fractures while debonding.[25] Then, silane primer (Ormco Porcelain Primer, Glendora, California, USA), that improved surface wettability to resin, was applied to the etched porcelain surface.[26,27] Also, it was concluded that both tensile and shear testing caused fracture of the porcelain, if silane coupling was used for increasing the bond strength of orthodontic adhesives.[9,28]

In this study, a light-cured composite resin (Light Bond, Reliance Orthodontic Products Inc. Itasca, Illinois, USA), was used to bond the ceramic brackets. It was reported that Light Bond has enough bond strength for bonding the orthodontic brackets.[29]

Shear bond testing and thermocyling may be advised as a standard method of testing the bond strength of brackets to different surfaces.[4,6,30] In our study, shear bond testing after orthodontic bonding and thermocyling between 5 and 55°C was done for testing the bond strength of ceramic brackets bonded to three types of ceramic crown materials. Generally, 24 hours is considered as prudent time for storage in water. Thermocycling of 500 cycles is applied for storage.

In this study, the lowest bond strength result, 7.09 MPa, was obtained in the conventional porcelain-fused-to-metal crown group and the highest bond strength result, 8.93 MPa, was found in the porcelain-fused-to-zirconia crown group. No statistically significant differences were found in the bond strengths between IPS e.max ceramic crown and porcelain-fused-to-zirconia crown groups. Cohesive fractures maybe seen on the ceramic surface, if the bond strength results between the ceramic and the composite resin are greater than 13 MPa.[26] In our study, the bond strength values in the three groups did not exceed this value.

In this study, modes of failure of groups are scored according to the ARI. ARI-1 type of failures was seen only in the IPS e.max ceramic crown group and porcelain-fused-to-zirconia crown group. No statistically significant difference was observed between the ARI scores for the three types of crowns ($P > 0.05$).

Conclusion

Using silane coupling agents and hydrofluoric acid would be appropriate for chemical alteration of the porcelain surface when intraoral orthodontic applications are needed.

There was no significant difference in the ARI scores between the three types of ceramic crowns.

No statistically significant differences were found in the bond strengths between IPS e.max ceramic crown and porcelain-fused-to-zirconia crown groups. But in the IPS e.max ceramic crown and porcelain-fused-to-zirconia crown groups, significantly higher bond strength values were obtained than conventional porcelain-fused-to-metal crown group.

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