Evaluation of the shear bond strength of different ceramic bracket base designs

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With the introduction of the acid-etch bonding technique in 1955,[1] the concept of bonding various resins to enamel has created applications in all aspects of dentistry including the bonding of orthodontic brackets.[2-8] This approach has several advantages: enhanced potential for plaque removal by the patient,[5,9] reduced soft tissue irritation and hyperplastic gingivitis, elimination of the need for separation,[5,9] absence of post-treatment band spaces, facilitation of application of attachments to partially erupted teeth, reduced danger of decalcification with loose bands,[9,10], easier detection and treatment of caries, and a much more esthetic appearance for the patient.[2]

An increasing number of adults are seeking orthodontic treatment primarily for cosmetic reasons. These patients desire high quality orthodontic treatment that is also less obtrusive. This has led to the development of new brackets with a more pleasing and acceptable appearance. Polycarbonate brackets were introduced in the early 1970s, but their distortion under torsional forces and from water absorption limited their use.[2,11] In an attempt to improve their properties, manufactures reinforced the plastic brackets with metal bracket slots and ceramic fillers.[2] Despite their efforts, the problems of slot distortion and staining restricted their use.

In 1986, brackets made of polycrystalline alumina or sapphire ceramic material became available.[2] Unlike earlier plastic brackets, ce-

Abstract

The purpose of this study was to compare the Ceramaflex bracket with a traditional ceramic orthodontic bracket with regard to shear bond strength and bond failure location. Forty newly extracted human premolars were randomly divided into two groups. Twenty Ceramaflex brackets (TP Orthodontics Inc, LaPorte, Ind) and 20 Transcend 6000 brackets (Unitek Corp, Monrovia, Calif) were bonded to the teeth using the same bonding system (Right On, TP Orthodontics Inc, LaPorte, Ind). A Zwick Universal Test machine (Zwick Gm bH & Co, Ulm, Germany) was used to determine the shear bond strength for each bracket. After debonding, the teeth and brackets were examined under 10x magnification. After debonding, the amount of resin material adhering to the enamel surface was assessed according to the Adhesive Remnant Index (ARI).[15] The results of this study suggest that Ceramaflex brackets have a significantly lower bond strength than traditional ceramic brackets. On the other hand, the bond failure location of the Ceramaflex bracket was consistently more favorable, i.e., occurring at the ceramic bracket-polycarbonate base.

Key Words

Brackets • Base • Bonding • Shear strength

Submitted: February 1996 **Revised and accepted:** April 1996 Angle Orthod 1997;67(3):179-182.

Table 1
Descriptive statistics and comparisons of shear bond strength in MPa for the two brackets tested

Group tested	N	$\bar{x}$	SD	Range	F-Value
Ceramaflex®	20	8.8	3.5	3.3-16.1	0.0133
Transcend 6000	20	14.4	6.4	3.7-26.8	

N= sample number, $\bar{x}$ = mean, SD = standard deviation

Table 2
Residual adhesive ratings

Group	Adhesive Remnant Index 1	2	3	4	5	Chi Square test
Ceramaflex®	17	0	1	1	1	$\chi 2=0.213$
Transcend 6000	4	8	7	0	1	

*1 All composite remained on tooth; 2 >90% of composite on tooth; 3 <10% but >90% of composite on tooth; 4 <10% of composite on tooth; 5 No composite on tooth

ramic brackets resist staining, discoloration, and are chemically inert to oral fluids. A disadvantage of inert brackets is their failure to form bonds with acrylic and diacrylic adhesives.[2] As a result, several methods of retention have been used, including the application of a silane coupler in order to achieve a clinically useful bond strength.[2,12,13]

One concern regarding ceramic brackets is the difficulty of removing them from the enamel surface during debonding. Ceramic materials, in general, are extremely brittle, and minor cracks result in a significant reduction in the load required for fracture.[14] As a result, a number of approaches for debonding ceramic brackets have been suggested, including thermal, ultrasonic, and mechanical debonding.[15] Some of the complications reported during debonding include bracket shattering and damage to the enamel surface.[16] More recently, a new type of ceramic bracket was introduced namely the Ceramaflex (TP Orthodontics Inc, LaPorte, Ind), bracket. The manufacturer suggests that these brackets are removed as easily as metal brackets and yet maintain the esthetics of the traditional ceramic bracket. The Ceramaflex bracket uses a thin polycarbonate base attached to ceramic bracket wings. The interface between the adhesive and bracket is thus an adhesive/polycarbonate bond and not an adhesive/ceramic bond. To date only two independent studies using the Ceramaflex bracket have been published. Fox et al.[17] compared the Ceramaflex bracket with traditional metal edgewise brackets, and reported that the two brackets had similar mean bond strengths (57.3 N to 55.3 N, respectively). They concluded that the Ceramaflex brackets were more unpredictable and less reliable but were easily removed from the teeth without damage to either the bracket or the enamel surface. Bordeaux et al.[18] evaluated shear bond strengths and fracture sites of the Ceramaflex bracket and three other ceramic brackets. They reported the Ceramaflex brackets to have a significantly lower mean shear bond strength than any of the three conventional ceramic brackets tested. Furthermore, there was no statistically significant difference in bond strengths between the other brackets. Fracture sites were evaluated for all brackets and the Ceramaflex bracket was reported to fail at the adhesive-bracket interface in 100% of the samples.

The literature indicates that there is some controversy regarding the bond strength of the new Ceramaflex bracket when compared with other brackets available on the market. Therefore, the purpose of this study was to compare the Ceramaflex bracket with a traditional ceramic orthodontic bracket with regard to shear bond strength and bond failure location.

Materials and methods

Teeth

Forty newly extracted human premolars were collected and stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included: intact buccal enamel; not subjected to any pretreatment chemical agents, such as hydrogen peroxide; no cracks due to the pressure of the extraction forceps; and no caries. The teeth were cleansed and then polished with nonfluoridated pumice and rubber prophylactic cups for 10 seconds. The teeth were separated into two groups of 20 each.

Bonding procedure

A 37% phosphoric acid gel was applied to the buccal surface of each tooth for 60 seconds. The teeth were then rinsed with a water spray for 30 seconds and dried with an oil-free air source for 20 seconds. The buccal surfaces of the etched teeth appeared chalky white in color.

Right On (TP Orthodontics Inc, LaPorte, Ind) bonding system was used. Bonding procedures were performed according to the manufacturer's instructions. This bonding system is recommended by the manufacturer for use with the Ceramaflex bracket.

Brackets

Twenty Ceramaflex brackets and twenty Transcend 6000 brackets, (Unitek Corp, Monrovia, Calif) were mounted using the same bonding system. Each bracket was subjected to 300 grams of force applied perpendicular to the enamel surface using a Corex Gauge (Haag-Strait, Bern, Switzerland) for 10 seconds, followed by removal of excess bonding resin using a small scaler. The average surface area of the Ceramaflex bracket base was 15.60 mm^2 and the Transcend 6000 base was 12.02 mm^2.

Testing for bond strength

The teeth were embedded in acrylic placed in phenolic rings (Buehler, Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surfaces of the teeth perpendicular to the bottom of the mold. All samples were stored in deionized water at 37°C for 48 hours. Each tooth was oriented with the testing device as a guide so its labial surface was parallel to the applied force during the shear strength test. A steel rod with one flattened end was attached to the crosshead of a Zwick test machine (Zwick Gm bH & Co, Ulm, Germany). An occlusogingival load was applied to the bracket producing a shear force at the bracket-tooth interface. A computer electronically connected with the Zwick test machine recorded the results of each test. Shear bond strengths were measured at a crosshead speed of 5 mm/min.

Evaluation of residual adhesives

After debonding, the teeth and brackets were examined under 10x magnification. Any adhesive remaining after bracket removal was assessed according to the Adhesive Remnant Index (ARI)[15] and scored with respect to the amount of resin material adhering to the enamel surface. The ARI scale ranges from 5 to 1, with 5 indicating that no composite remained on the enamel; 4, less than 10% of composite remained on the tooth surface; 3, more than 10% but less than 90% of the composite remained on the tooth; 2, more than 90% of the composite remained; and 1, all of the composite remained on the tooth, along with the impression of the bracket base. The ARI scores were also used as a more complex means of defining the site of bond failures between the enamel, the adhesive, and the bracket base.

Statistical analysis

Descriptive statistics including the mean, standard deviation, and minimum and maximum values were calculated, for each group of teeth tested. Analysis of variance was used to determine if significant differences existed between the various groups. If a significant difference was present, a Duncan's Multiple Range test was used to identify which of the groups were different. The Chi Square test was used to determine significant differences in the ARI scores between the different groups. Significance for all statistical tests was predetermined at $P \leq 0.05$.

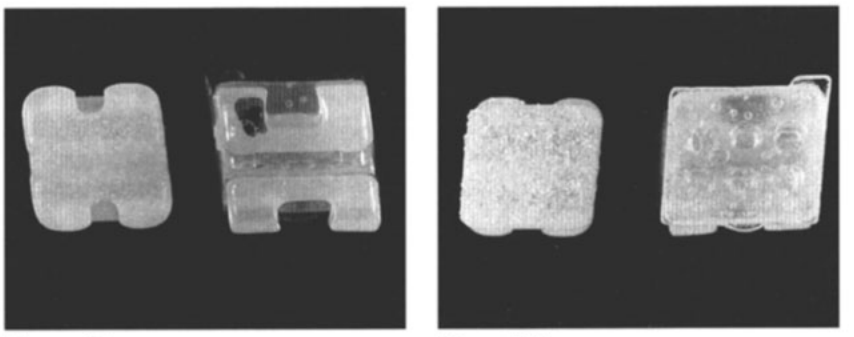

Figure 1A Figure 1B

Figure 1A-B
Front and back views of the two brackets used, Transcend 6000 on the left and Ceramaflex on the right.

Results

Bond strength comparisons

Descriptive statistics for the shear bond strength for the two groups are presented in Table 1. The results of the Analysis of Variance comparing the two groups indicated that the Ceramaflex bracket had a statistically significant ($P=0.0133$) mean debonding force (8.8 ± 3.5 MPa) compared with the Transcend 6000 bracket (14.4 ± 6.4 MPa).

Amount of residual adhesive

The Adhesive Remnant Index (ARI) was used to determine the bond failure location between the two groups. Table 2 lists the frequency of ARI scores and the results of the Chi Square test comparisons. The Chi Square test indicated that no statistically significant differences were present between the various groups ($P=0.213$).

Discussion

With the introduction of ceramic brackets, clinicians have been concerned about the possibility of enamel fracture at the time of debonding.[16] As a result, a number of modifications have been introduced in the design of ceramic bracket bases in an attempt to make the debonding procedure safer for the patient and less stressful for the clinician.

The findings of this study indicate that a new orthodontic bracket using a polycarbonate base has a bond strength that is significantly lower than the bond strength of a comparable ceramic bracket without a polycarbonate base. The bond strengths obtained in this study (8.8 ± 3.5 MPa) compare favorably with that obtained by Bordeaux et al.[18] (8.8 MPa). On the other hand, the mean bond strength observed for the

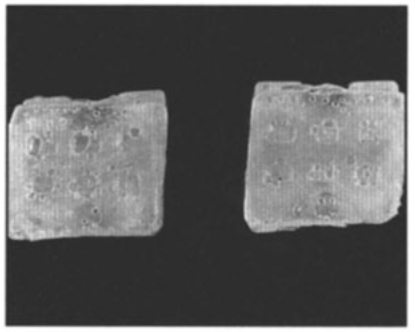

Figure 2A

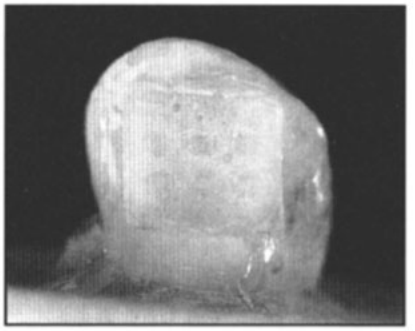

Figure 2B

Figure 2A-B
A: Ceramic part of the Ceramaflex bracket is removed during mechanical debonding.
B: Polycarbonate base and adhesive remain attached to the tooth for subsequent removal using high speed instrumentation.

Ceramaflex bracket (8.80 MPa) was considerably less than the Transcend 6000 bracket (14.20 MPa). This difference supports the findings of Bordeaux et al. that Ceramaflex brackets do not provide the same bond strength as more traditional brackets. On the other hand, the bond strength is above the minimal force levels suggested by Reynolds[11] as being clinically acceptable (5.9 to 7.8 MPa).

Although the two bracket types did not exhibit significant differences in the bracket failure location, the Ceramaflex bracket exhibited a more consistent bond failure location, specifically between the ceramic bracket and polycarbonate base in 17 out of 20 debondings (Figure 2A and B). This is a more desirable bond failure location because it minimizes the stress on the enamel surface during debonding. As a result, the clinician has to consider these two charactistics of the Ceramaflex bracket, namely a relatively lower shear bond strength that might not withstand relatively heavy orthodontic forces, but a more favorable debonding site that leaves most of the adhesive on the enamel surface. This residual adhesive will then need to be removed from the enamel surface.

Conclusions

The results of this study suggest that the Ceramaflex bracket with the polycarbonate base has a significantly lower bond strength than traditional ceramic brackets. On the other hand, the bond failure location of the Ceramaflex bracket was consistently more favorable, i.e., at the ceramic bracket-polycarbonate base.

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