sciendo DOI: 10.2478/aoj-1997-0010

Shear bond strength of ceramic brackets to resin-composite surfaces

Ekachai Chunhacheevachaloke
DDS, MDSc
Faculty of Dentistry
Srinakharinwirot University,
Thailand.

Martin J. Tyas
BDS, PhD, GradDipHlthSc, AFCHSE, CHE, FADM, FICD, FRACDS
Reader, School of Dental Science,
University of Melbourne,
Australia.

In this study, two types of ceramic brackets — monocrystalline and polycrystalline — were bonded to unroughened and roughened resin-composite discs using a light-cured orthodontic adhesive, and the bonds tested under shear stress in a universal testing machine. There was no significant difference in the shear bond strength between the combinations of ceramic brackets, and between the surface treatments of the resin composite. A higher frequency of resin-composite fracture was observed with the polycrystalline brackets (12/20) than with the monocrystalline ceramic brackets (7/20). It is concluded that debonding any type of ceramic bracket from a resin-composite surface may cause damage to the resin composite itself.
Aust J Orthod 1997; 15: 10-15

Key Words: Ceramic bracket, resin composite, orthodontic bonding, shear bond strength.

Introduction

Resin composite has been used in Dentistry since the late 1950s when the development of the BIS-GMA molecule satisfied many of the requirements for the resin matrix of a dental composite, such as increased stiffness. With this breakthrough, composite materials rapidly replaced silicate cement and acrylic resins for aesthetic restoration of anterior teeth,[1] and they are now the materials of choice for restoring traumatised anterior teeth of the adolescent population.[2] Composite veneers are also frequently used in patients with dental fluorosis, tetracycline-stained teeth and for other aesthetic reasons.

Up to 24 per cent of adults now comprise an orthodontic case load.[9] Newman[10] reported that most of these patients are females who are strongly motivated, primarily for cosmetic reasons. These patients, together with an increasing number of adolescents who are similarly motivated, are demanding high quality orthodontic treatment which is as unobtrusive as possible.

Patients who have had resin-composite restorations and who are similarly concerned about aesthetics, would obviously prefer to have ceramic brackets fitted to their teeth. As these restorations are now more commonly used, this research was undertaken in order to investigate the shear bond strength of two particular ceramic brackets to resin composite, and to assess the effect on bonding of roughening the resin-composite surface.

Literature Review

It has been reported that the strength of repaired resin composite is reduced by 20 to 60 per cent of the strength of the original material. Söderholm[3] considered that the main mechanism of bonding between 'new' and 'old'

Received for publication: July 1995.
Accepted: April 1997.

resin composite is mechanical. He based this premise on the presence of smeared scratches on the prepared surface of the 'old' composite, indicating that a localised high temperature increase would have occurred during such preparation, thereby increasing the amount of surface polymerization; the resulting increased cross-link density would render chemical bonding of the 'new' resin unlikely.

Factors most likely to influence the bond between old resin composite and new resin composite include: the wettability of the surface of the composite (the least viscous resin composite gives the best bond strength[4]); the amount and chemical activity of the available resin for bonding (as fewer untreated methacrylate groups remain as the restoration ages, chemical bonding is less likely[5]); and the effect of surface treatment prior to repair (polishing was found to cause a reduction of repair bond strength;[6,7] surface roughening was responsible for the decreased repaired strength, however, the strength was restored to a clinically acceptable level by applying a bonding agent prior to repair[7,8]).

The first ceramic brackets, made of either polycrystalline or monocrystalline alumina,[11] became available in late 1986. Three mechanisms are used for their bonding: mechanical retention via indentations and/or undercuts in the bracket base; chemical bonding using an adhesive intermediate;[12] or a combination of the two.[13] Swartz[12] suggested that using a no-mix or a one-step bonding material with ceramic brackets is probably contra-indicated, the major problems being discoloration of the brackets due to the high concentration of amine polymerization accelerator in the adhesive, and the reduced bond strength obtained with mechanically-retained brackets because the grooves and indentations are too large for the adhesive to achieve sufficient bond strength.

Several experiments have been performed to test the effect of bonding systems on the shear bond strength of ceramic brackets to enamel. Comparisons between these studies are difficult because of the variations in the type of adhesives used (light-cured or self-cured) and the different compositions used by each manufacturer. Even though Swartz[12] has warned practitioners against using a no-mix adhesive with a ceramic bracket, subsequent studies showed a satisfactory bond strength with this material.[14-18] In general, any orthodontic adhesive may be used for bonding a ceramic bracket; however, it is probably more advantageous to use a light-cured bonding material as direct illumination is possible: the illumination time being less than that required for a metal bracket because of the translucency of the ceramic bracket.[14]

A survey published in 1992 of British orthodontists' experience of the clinical performance of ceramic brackets showed that nine per cent had observed enamel fracture during debonding, and 21 per cent had experienced enamel cracking.[19] Because of these negative aspects of chemically-bonded brackets, a second-generation polycrystalline bracket, Transcend Series 2000,* was manufactured. The chemical retention mediated by the silane treatment of the base of the first-generation Transcend bracket was replaced by mechanical retention by means of glass fragments fused to the base, thereby creating a rough fibrous surface.[13,20,21] As a result, a reduction in enamel damage has been reported with the second-generation bracket.[21,22]

The manufacturer of the Starfire‡ bracket (a monocrystalline product with chemical retention) has claimed not to have changed its retention system; however, Eliades *et al.*[22] indicated that the recent Starfire bracket did appear to be different as fewer cohesive bracket failures were reported than in a previous study by Viazis *et al.*[23]

The required shear bond strength to achieve adequate retention of bracket to tooth is not known. However, previous studies have reported bond strength values in the 12.1 to 18.8 MPa range for metal brackets to enamel,[14,24,25] which gives a baseline for comparison with ceramic brackets.

Mean shear bond strengths to enamel ranged from 17.0 to 25.9 MPa for the Transcend Series 2000 brackets[15,21] and 15.7 to 21.73 MPa for the Starfire brackets.[16,17] Both ranges of values are higher than those for conventional metal brackets.

Materials and Methods

Forty cylindrical resin-composite buttons were prepared in a plastic mould 7 mm in diameter and 3 mm deep. Silux,‡‡ a light-cured resin composite, was placed in the mould and photocured using a Visilux‡‡ unit for 20 seconds for each of two increments. The second increment was covered with a mylar strip and compressed with a glass slab to achieve a flat surface. Each resin-composite button was mounted in self-cured acrylic resin, cured in a cylindrical mould 24 mm in

* 3M/Unitek, Monrovia, CA.
‡ "A" Company, San Diego, CA.
‡‡ 3M Dental Products, St Paul, MN

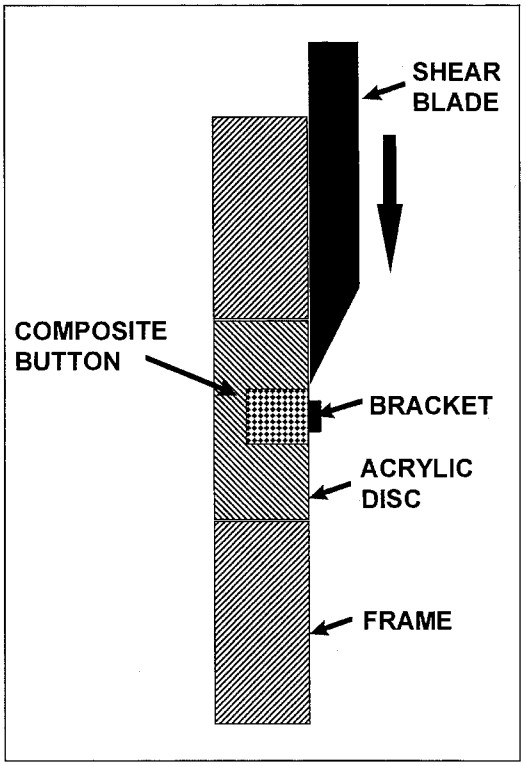


Figure 1. Diagrammatic representation of experimental apparatus.

diameter and 10 mm deep. The acrylic-resin disc was allowed to set at room temperature for 20 minutes and then removed from the mould.

Each button was initially ground with 240-grit silicon carbide paper, then with 1200-grit silicon carbide paper under running tap water. In order to ensure a flat resin-composite surface at right angles to the long axis of the disc, a plastic block was used to secure each acrylic disc when being polished. After polishing, all samples were placed in distilled water at 37°C for 24 hours.

The resin-composite surfaces were polished using pumice in a rubber cup on a low-speed handpiece, and washed and dried using a triplex air-water syringe. Surface abrasion was performed on the twenty composite buttons by running a coarse Soflex‡‡ disc on a low-speed handpiece twice across the acrylic and resin-composite surfaces. Each button was treated with 37 per cent phosphoric acid gel‡‡ for 15 seconds, the acid rinsed from the resin surface with water from the triplex syringe for 20 seconds, and the button dried with air from the triplex syringe for 20 seconds.

Twenty Starfire (monocrystalline) and twenty Transcend Series 6000 (polycrystalline) Edgewise upper right central incisor brackets were used in this study. The dimensions of the bracket bases were 3.350 mm x 3.575 mm (11.976 mm^2) and 3.250 mm x 3.851 mm (12.512 mm^2) for the Transcend Series 6000 and Starfire brackets, respectively. (The Transcend series 6000 has the same base as the Transcend Series 2000.) Ten brackets of each type were bonded to the unroughened composite surfaces, and ten to the roughened composite surfaces.

Transbond* (a light-cured bonding adhesive) was used following the manufacturer's instructions as follows. Primer was applied to the resin-composite surface and the bracket base, and air-blown to obtain a thin layer. The adhesive was pasted over the whole bracket base, the bracket firmly seated by finger pressure on the resin-composite surface and the excess adhesive removed with a probe. The adhesive was light-cured for 20 seconds with the light held 2 mm vertically above the bracket. Each sample was stored in distilled water at 37°C for 24 hours, and secured in a loading jig for shear testing (International Organization for Standarization Technical Report 7405) on a universal test machine. The blade was placed at the adhesive/bracket interface on the long side of the bracket, and the test performed with a 50 kg load cell and a cross-head speed of 5 mm/min (Figure 1).

The shear bond strength of each bracket was calculated using the formula: BS = 9.807F/A, where BS is the bond strength (MPa), F is the debonding force (kg), and A is the area of the bracket base (mm^2). The bracket bases were measured using a micrometer, and the individual and group mean bond strengths calculated.

Each debonded bracket and resin-composite surface was examined under a binocular microscope at 20x magnification. The predominant site of failure was classified as one of the following:

1. A/B: Adhesive/bracket interface. No adhesive remained on the bracket surface;
2. A/CR: Adhesive/resin-composite interface. No adhesive remained on the resin-composite surface;
3. COMB: Combination failure. The adhesive failed, and remained on both the bracket and the resin composite;
4. B#: The bracket fractured during removal. Adhesive remained attached to the resin composite;
5. CR#: The resin composite fractured during removal. Resin composite and adhesive remained attached to the bracket base.

* 3M/Unitek, Monrovia, CA.
‡‡ 3M Dental Products, St Paul, MN

Table I. Shear bond strengths of brackets to resin composite.

BRACKET AND SURFACE TREATMENT	MEAN (MPa)	STANDARD DEVIATION (MPa)	RANGE (MPa)
Transcend (unroughened)	19.1*	4.66	13.0–28.9
Transcend (roughened)	19.2*	6.75	13.6–36.1
Starfire (unroughened)	18.6*	7.25	9.6–33.1
Starfire (roughened)	17.1*	5.73	9.0–24.8

n = 10
* Denotes no significant difference between these groups.

Table II. Type of failure interface; number of samples.

BRACKET AND SURFACE TREATMENT	A/B	A/CR	COMB	B#	CR#
Transcend (unroughened)	5	0	0	0	5
Transcend (roughened)	2	1	0	0	7
Starfire (unroughened)	2	0	5	0	3
Starfire (roughened)	6	0	0	0	4

n = 10
* Denotes no significant difference between these groups.

One-way analysis of variance (ANOVA) was used to test the mean shear bond strength, and a chi-square test was used to test each particular failure site of the above five classifications of failure.

Results

Table I shows the mean shear bond strengths; there was no significant difference between the four experimental groups ($p \leq 0.05$).

The failure sites of the four experimental groups are shown in Table II. The incidence of resin-composite fracture was higher in the Transcend group than in the Starfire group. Based on this high rate of resin-composite damage on debonding, the failure interface in all classifications was assessed as 'satisfactory' if the interface occurred either as A/B, A/CR, or COMB; the 'unsatisfactory' group comprised the total number of resin-composite fractures. Chi-square analysis revealed no significant difference ($(2 = 0.1$, $df = 1$, $p \leq 0.05$) for the type of bracket and surface treatment in producing 'satisfactory' or 'unsatisfactory' outcomes when the brackets were debonded.

Discussion

A search of the literature revealed no other studies of bonding of orthodontic brackets to resin-composite surfaces, therefore it was not possible to make comparisons. Accordingly, the studies of the repair of resin-composite restorations have been selected for comparison because the authors' study closely resembles the clinical situation of adding new resin composite to an existing resin-composite surface. However, the differences between the various orthodontic adhesives and restorative resin composites make direct comparisons of dubious value.

In restorative dentistry, the surface cutting of resin composite prior to repair usually results in a decrease in bond strength, whether the cutting is performed with a crosscut fissure bur,[26] a rotary abrasive stone[27] or an abrasive wheel.[5] Gregory *et al.*[28] concluded that repairs rely upon residual unconverted carbon bonds for chemical bonding, as well as mechanical retention. Less conversion of, or increases in. the resin matrix in the primary specimen should provide increased linkage for a self-cured repair. However, Vankerckhoven *et al.*[7] and Mitsaki-Matsou *et al.*[8] reported that the repair strength can be restored to acceptable levels by applying a bonding agent prior to repair; and Boyer *et al.*[26] and Chiba[29] reported that the etching of cut composite surfaces did not significantly increase retention of repaired specimens.

The results of the present study indicated no difference in mean shear bond strength of Transcend Series 6000 and Starfire ceramic brackets when they were bonded to roughened or unroughened resin-composite surfaces with Transbond light-cured orthodontic adhesive. Factors other than polishing, surface abrasion, and coating with bonding material may have influenced the debonding test: for example, non-shear forces might have occurred because of factors such as the position of the samples and the testing apparatus, and variations in the thickness of the resin-composite adhesives.

Because the fracture in the resin-composite occurred in a different number of specimens in each group, the recorded bond strength in those samples was lower than the adhesive bond strength at the resin-composite/adhesive interface, and lower than the ceramic/adhesive

interface: that is, both the bond strength between the bracket and the adhesive, and the bond strength between the adhesive and the resin composite are higher than the cohesive strength of the resin composite. The high number of composite fractures indicates that the bond strength of a ceramic bracket to resin composites is excessively high, and may result in damage; however, there has been a reported reduction in enamel damage associated with the use of the second-generation ceramic brackets.[21,22,30]

Although it has been suggested that, on debonding, fracture should occur at the adhesive/enamel interface,[20] the procedure is often associated with enamel damage. Thus, a more desirable site for fracture is the adhesive/bracket interface, leaving adhesive on the enamel which can then be polished off. This suggests a need for an adhesive with a bond which is weaker to the bracket than to the enamel. In order to achieve this, modification of the etching procedure and/or an altered concentration of etching acid were cited by Carter[31] as alternative ways to reduce the bond strength to enamel. Bishara *et al.*[32] proposed growing crystals on the enamel, thereby producing a mechanical bond by which ceramic brackets may be attached. An adhesive mixed with a plasticizer which facilitates the removal of the adhesive was tested by Starling and Love;[33] however, it is yet to be seen if this procedure is practical and applicable to the bonding of ceramic brackets to resin composite.

Some recent attempts to debond ceramic brackets include electrothermal debonding[34] and laser-aided debonding;[35] however, these instruments are very costly at present.

Acknowledgments

The authors acknowledge the advice of Associate Professor V.C. West and Dr S. D'Adamo; and the assistance of Mr D.A. Cheadle in the preparation of test equipment.

Address for correspondence and reprints:

Professor M.J. Tyas
School of Dental Science,
The University of Melbourne.
711 Elizabeth Street,
Melbourne Victoria 3000
Australia

References

1. Phillips RW. Skinner's science of dental materials, 9th Ed., Philadelphia, W.B. Saunders Company, Philadelphia. 1991.
2. Jordan RE, Suzuki M, Gwinnett AJ et al. Restoration of fractured and hypoplastic incisors by the acid etch technique. J Am Dent Assoc 1977; 95: 795-803.
3. Söderholm KJM. Flexure strength of repaired dental composites. Scand J Dent Res 1986; 94: 364-9.
4. Causton BE. Repair of abraded composite fillings. Brit Dent J 1975; 139: 286-8.
5. Boyer DB, Chan KC, Reinhardt JW. Build-up and repair of light-cured composites: bond strength. J Dent Res 1984; 63: 1241-4.
6. Davidson CL, Duysters PPE, De Lange C et al.. Structural changes in composite surface material from dry polishing. J Oral Rehab 1981; 8: 431-9.
7. Vankerckhoven H, Lambrechts P, Van Beylen M et al.. Unreacted methacrylate groups on the surfaces of composite resins. J Dent Res 1982; 61: 791-6.
8. Mitsaki-Matsou H, Karanika-Kouma A, Papadogiannis Y et al.. An in-vitro study of the tensile strength of composite resins repaired with the same or another composite resin. Quintessence Int 1991; 22: 475-81.
9. Gottlieb EL, Vogels DS. 1983 Orthodontic practice study. Part 2: practice success. J Clin Orthod 1984; 18: 247-53.
10. Newman GV. Adhesion and orthodontic plastic attachments. Am J Orthod 1969; 56: 573-88.
11. Birnie D. Orthodontic materials update. Ceramic brackets. Brit J Orthod 1990; 17: 71-5.
12. Swartz ML. Ceramic brackets. J Clin Orthod 1988; 22: 82-8.
13. Ghafari J, Skanchy TL, Mante F. Shear bond strength of two ceramic brackets. J Clin Orthod 1992; 26: 491-3.
14. Odegaard J, Segner D. Shear bond strength of metal brackets compared with a new ceramic bracket. Am J Orthod Dentofac Orthop 1988; 94: 201-6.
15. Ostertag AJ, Dhuru VB, Ferguson DJ et al. Sbear, torsional, and tensile bond strengths of ceramic brackets using three adhesive filler concentrations. Am J Orthod Dentofac Orthop 1991; 100: 251-8.
16. Chaconas SJ, Caputo AA, Niu GS. Bond strength of ceramic brackets with various bonding agents. Angle Orthodontist 1991; 61: 35-42.
17. Winchester LJ. Bond strengths of five different ceramic brackets: an in-vitro study. Eur J Orthod 1991; 13: 293-305.
18. Carty G, Tyas MJ. Shear bond strength of a mechanically retained ceramic bracket. Aust Ortho J 1993; 13: 13-18.
19. Gibbs SL. Clinical performance of ceramic brackets: A survey of British orthodontists' experience. Brit J Orthod 1992; 19: 191-7.
20. Harris AMP, Joseph VP, Rossouw PE. Shear peel bond strengths of esthetic orthodontic brackets. Am J Orthod Dentofac Orthop 1992; 102: 215-9.

21. Forsberg CM, Hagberg C. Shear bond strengths of ceramic brackets with chemical or mechanical retention. Brit J Orthod 1992; 19: 183-9.

22. Eliades T, Viazis A, Lekka M. Failure mode analysis of ceramic brackets bonded to enamel. Am J Orthod Dentofac Orthop 1993; 104: 21-6.

23. Viazis AD, Cavanaugh G, Bevis RR. Bond strength of ceramic bracket under shear stress: An in vitro report. Am J Orthod Dentofac Orthop 1990; 98: 214-21.

24. Gwinnett AJ. A comparison of shear bond strengths of metal and ceramic brackets. Am J Orthod Dentofac Orthop 1988; 93: 346-8.

25. Joseph VP, Rossouw E. The shear bond strengths of stainless steel and ceramic brackets used with chemically and light-activated composite resins. Am J Orthod Dentofac Orthop1990; 97: 121-5.

26. Boyer DB, Chan KC, Torney DL. The strength of multilayer and repaired composite resin. J Prosthet. Dent 1978; 39: 63-7.

27. Lloyd CH, Baigrie DA, Jeffrey IW. The tensile strength of composite repairs. J Dent 1980; 8: 171-7.

28. Gregory WA, Berry S, Duke E et al. Physical properties and repair bond strength of direct and indirect composite resins. J Prosthet Dent 1992; 68: 406-11.

29. Chiba K. Adhesion of the subsequently added composite resin. J Dent Res 1983; 62 (Abst. 38): 471.

30. Viazis A, Nakajima H, Kleven J. Shear bond strengths of three new ceramic brackets. J Clin Orthod 1993; 27: 539-42.

31. Carter RN. Clinical management of ceramic brackets. J Clin Orthod 1989; 23: 807-9.

32. Bishara SE, Fehr DE, Jakobsen JR. A comparative study of the debonding strengths of different ceramic brackets, enamel conditioners, and adhesives. Am J Orthod Dentofac Orthop 1993; 104: 170-9.

33. Starling KE, Love BJ. Plasticization of adhesive to improve debonding of ceramic brackets. J Clin Orthod 1993; 27: 319-22.

34. Bishara SE, Trulove TS. Comparisons of different debonding techniques for ceramic brackets: an in vitro study. Part I. Background and methods. Am J Orthod Dentofac Orthop 1990; 98: 145-53.

35. Strobl K, Bahns TL, Willlham L et al.. Laser-aided debonding of orthodontic ceramic brackets. Am J Orthod Dentofac Orthop 1992; 101: 152-8.