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Comparison of initial shear bond strengths of plastic and metal brackets

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SUMMARY The aims of this study were to compare initial and 24 hour shear bond strengths of plastic brackets with a mechanical base (Spirit MB) and metal brackets, using two different adhesives (System 1+ and Enlight), and to examine the modes of failure after debonding. Eighty extracted human premolars were used. After bonding, shear bond strengths in half the sample were tested within 30 minutes. The remaining 50 per cent were placed in a 37°C distilled water bath for 24 hours before testing.

The results showed that the effects of the two adhesives and the interaction of the two time intervals and the two bracket types on shear bond strength were significantly different ($P < 0.05$ and $P < 0.0001$, respectively). Six of the 10 groups were found to have less than 50 per cent of the adhesive remaining on the tooth surface after debonding in the 24 hour metal bracket–System 1+ group, but most specimens in the other seven groups had more than 50 per cent of the adhesive left. It is concluded that System 1+ cannot provide sufficient initial bond strength for Spirit MB and may increase the risk of enamel fracture for metal brackets.

Introduction

Plastic brackets were introduced in the 1960s (Newman, 1969), as an aesthetic alternative to metal ones. Some disadvantages of plastic brackets, such as discolouration, fragility, breakage under stress and low bond strengths, have been reported (Sinha and Nanda, 1997). Ceramic fillers and metal slot reinforcement of plastic brackets appear to improve their strength and rigidity (Feldner *et al.*, 1994; Alkire *et al.*, 1997). In the past, plastic brackets chemically bonded to a tooth surface required a plastic primer to increase their bond strength (Buzzitta *et al.*, 1982). A new generation of plastic brackets with a mechanical base was recently introduced to improve bond strengths without the use of a primer (Fernandez and Canut, 1999). The bond strengths of the plastic brackets were found to be sufficiently strong to provide successful clinical bonding (Urabe *et al.*, 1999; Liu *et al.*, 2002). However, when these types of bracket were bonded to teeth using System 1+ (Ormco Co., Orange, California, USA) according to the manufacturer's instructions, many of the brackets loosened during fixing of the main wire 10 minutes after bonding. There have been no previous reports of the initial bond strengths of plastic brackets with a mechanical base. The objectives of this study were to compare the initial and 24 hour shear bond strengths of plastic brackets with a mechanical base and metal brackets using two different adhesives, and to examine the modes of failure after debonding.

Materials and methods

Brackets

Two types of bracket, a metal bracket with a mesh base (Mini Diamond, Ormco Co.) and a plastic bracket with a metal slot and a mechanical base (Spirit MB, Ormco Co.) (Figure 1), were chosen. All were premolar brackets used in the standard edgewise technique. The average bracket base areas were 9.73 and 11.07 mm^2 for the metal and plastic brackets, respectively.

Adhesives

Two different orthodontic adhesives, System 1+ (Ormco Co.) and Enlight (Ormco Co.), were used. System 1+ is a urethane modified dimethacrylate resin and a no-mix chemically-cured adhesive. Enlight is a Bis-GMA resin and a one-paste fluoride-releasing light-cure adhesive.

Test piece preparation

In total, 80 sound human premolars extracted for orthodontic reasons were selected for bonding. After the premolars had been polished with pumice powder for 15 seconds, they were washed with an air–water spray for 15 seconds and air-dried. The teeth were then divided into two groups. One group was prepared for testing the initial bond strength, and the other for bond strength testing after 24 hours.

In the first group, 20 plastic brackets and 20 metal brackets were adhered to the labial surfaces of the

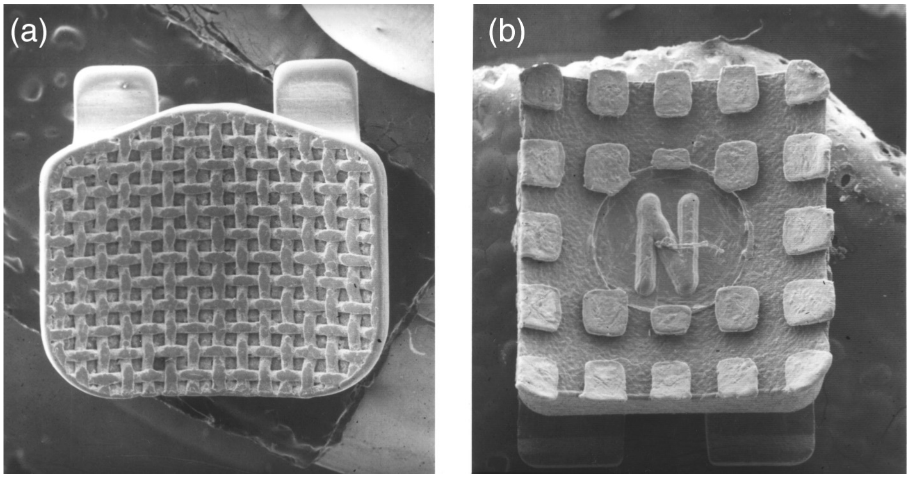

Figure 1 The base of metal (a) and plastic (b) brackets under ×25 scanning electron microscopy.

premolars using indirect bonding gel (Unitek, Monrovia, California, USA). A 0.017 × 0.025 inch^2 stainless steel sectional wire was inserted into the slot as a guide and tied by a ligature wire to the wings of the bracket and the teeth together with the guides embedded in die stone. After the stone was set, the brackets with the guides were rebonded to the teeth using two different orthodontic adhesives. In the second group, the brackets were directly bonded to the teeth and the 0.017 × 0.025 inch^2 sectional wire was tied as guides immediately after bonding. The teeth with the guides were then embedded in die stone.

Bonding procedure

The labial surfaces of the teeth were etched with 37 per cent phosphoric acid solution for 30 seconds, rinsed with a water spray for 10 seconds and thoroughly air-dried. Each group was then divided into four subgroups according to different combinations of brackets and adhesives. For Enlight bonding, a thin coat of Flurobond XM sealant (Ormco Co.) was applied to the tooth surface and Enlight paste on the bracket base. The bracket was positioned on the tooth surface, and pressure was applied. Excess paste was removed and the resin was cured using a light-cure machine (Ortholux™ XT; 3M Unitek) for 10 seconds for the plastic brackets and 30 seconds for the metal brackets. For the System 1+ bonding, System 1+ liquid activator was applied to both the tooth surface and the bracket base and paste to the activated bracket base.

Shear debonding test

Shear bond strengths of the first group were tested within 30 minutes of bonding. The means and standard deviations of the times for the four initial subgroups were: 14.1 ± 7.06 minutes for System 1+ metal group, 14.3 ± 5.12 minutes for System 1+ plastic group, 14.5 ± 8.77 minutes for Enlight–metal group and 15.2 ± 8.27 minutes for Enlight–plastic group. The specimens in the second group were placed immediately after bonding in a 37ºC distilled water bath for 24 hours. Following this, shear bond strengths were determined. The specimen was mounted in a universal testing machine (AG-2000E; Shimadzu, Kyoto, Japan), and shear bond strength was tested at a crosshead speed of 0.5 mm/minute.

Modes of failure

After testing shear bond strengths, the tooth surfaces were observed with a stereomicroscope (Stemi-2000-C; Zeiss, Jena, Germany) to evaluate the mode of failure and enamel fracture at ×25 magnification. Adhesive remnant index (ARI) scores (David *et al.*, 2002) were recorded for each specimen to determine the mode of failure. The scores were classified as: 1, no adhesive remaining; 2, less than 25 per cent of the adhesive remaining; 3, 25–50 per cent of the adhesive remaining; 4, 50–75 per cent of the adhesive remaining; 5, more than 75 per cent of the adhesive remaining; 6, all of the adhesive remaining on the tooth surface.

Statistics

The effects of three variables (two time intervals, two bracket types and two adhesives) and their interactions on shear bond strength were determined by multiple regression analysis. The ARI scores of the eight groups were assessed by one-way ANOVA and Tukey-Kramer HSD comparison.

Results

The shear bond strengths of the various combinations of brackets and adhesives are shown in Table 1. The effects of the two adhesives on shear bond strength were significantly different ($P < 0.05$). However, both the two time intervals and the two bracket types had no significant effects on shear bond strength. The effects of the interaction of the two time intervals and the two bracket types on shear bond strength reached statistical significance ($P < 0.001$), but the effects of other combinations did not.

The ARI scores and the number of enamel fractures are shown in Table 2. An ARI score of 6 was predominantly noted in the 24 hour plastic bracket–Enlight and initial metal bracket–Enlight groups, and an ARI score of 3 was predominant in the 24 hour metal bracket–System 1+ group. The difference was statistically significant ($P < 0.05$). There were five enamel fractures in the 24 hour metal bracket–System 1+ group, two in the 24 hour metal bracket–Enlight group, and one in the 24 hour plastic bracket–System 1+ and initial metal bracket–System 1+ groups. There were no enamel fractures in the other four groups.

Discussion

An increase in bond strength after 24 hour bonding for metal brackets has been reported in previous studies to be 3 MN/m^2 (Bryant *et al.*, 1987) and 7.5 MPa (Evans *et al.*, 2002). In the present study, an increase was found in the mean bond strength after 24 hour bonding for both metal and plastic brackets (5.2–5.4 and –0.2–1.4 MPa, respectively), but the effect of the two time intervals on shear bond strength was not significantly different. The results were inconsistent with previous findings.

Table 1 Shear bond strengths (MPa) of various combinations of brackets and adhesives.

	Initial shear bond strength	24 hour shear bond strength
SM	8.50 ± 4.28	13.90 ± 2.73
SP	2.90 ± 1.95	4.38 ± 1.34
EM	9.21 ± 5.36	14.41 ± 4.11
EP	6.58 ± 3.53	6.31 ± 1.39

S, System 1+; M, metal bracket; P, plastic bracket; E, Enlight.

Table 2 Adhesive remnant index (ARI) scores and number of enamel fractures for various combinations of brackets and adhesives.

	ARI scores						Number of enamel fractures
	1	2	3	4	5	6	
SM24	0	2	4	1	3	0	5
SP24	0	2	0	0	7	1	1
EM24	0	2	1	2	3	2	2
EP24	0	0	0	0	1	9	0
SMI	0	0	2	3	3	2	1
SPI	0	0	0	3	7	0	0
EMI	0	0	1	0	3	6	0
EPI	1	2	0	0	3	4	0

S, System 1+; M, metal; 24, 24 hours; P, plastic; E, Enlight; I, initial.
*$P < 0.05$.

The bond strengths of plastic brackets have been reported to be significantly lower than those of metal brackets (Reynolds and von Fraunhofer, 1977; Harris *et al.*, 1992; Blalock and Powers, 1995; Akin-Nergiz *et al.*, 1996; Nkenke *et al.*, 1997; Willems *et al.*, 1997; Urabe *et al.*, 1999; Guan *et al.*, 2001). The mean bond strength of Spirit MB has also been reported to be significantly lower than that of metal brackets in previous investigations by 6.45–8.05 and 12.01 MPa (Urabe *et al.*, 1999; Fernandez and Canut, 1999). The results of the present study showed that bond strengths of Spirit MB were lower than those of the metal brackets except for the initial–Enlight group, but the difference did not reach statistical significance. The fact that there was no difference between the metal brackets and Spirit MB might be because both had mechanical bases and could provide a similar mechanical interlock.

When the effects of interaction of different variables on shear bond strength were examined, a significant effect of interaction of the two time intervals and the two bracket types was found, as compared with other combinations ($P < 0.001$). This suggests that the bond strengths of the initial–plastic bracket subgroups were lower than those of the other combinations of time interval and bracket type, which caused many of the brackets to loosen during fixation to the main wire. Reynolds (1975) stated that a minimum bond strength of 5.9–7.9 MPa could result in successful clinical bonding. Thus, Enlight provided a sufficient bond strength for the plastic brackets, but System 1+ did not. The effect of the two adhesives on shear bond strength was significantly different ($P < 0.05$) in the present study. Reliance Phase II and Concise were found to provide sufficient bond strength for plastic brackets to be applied in previous studies (Fernandez and Canut, 1999; Urabe *et al.*, 1999). Enlight, Reliance Phase II and Concise belong to the Bis-GMA resins, whereas System 1+ is a urethane modified dimethacrylate resin. Thus, with plastic brackets, a Bis-GMA resin would be a better choice.

Enamel fractures during debonding of metal brackets have been reported, particularly when conditioners are of a higher concentration and conditioning times are extended (Sheen *et al.*, 1993; Wang *et al.*, 1994). In the present study, there were eight enamel fractures for the metal brackets but only one for the plastic brackets. As the same concentration of conditioner and conditioning times were used, the higher incidence of enamel fractures might be caused by the higher bond strengths observed in the metal bracket group. Ideally, to avoid enamel fracture, the modes of failure should occur between the bracket base and the adhesive rather than between the adhesive and the enamel (Zarrinnia *et al.*, 1995). In a previous study, 14 per cent of bond failures were found at the bracket–adhesive interface for metal brackets, and 92.9 per cent for Spirit MB (Urabe *et al.*, 1999). The modes of failure in the present investigation were different. Seventy per cent of bond failures were at the bracket–adhesive interface for the metal brackets, and 87.5 per cent for Spirit MB. Among the eight enamel fractures in the metal bracket group in the present investigation, six were bonded with System 1+ and two with Enlight. Therefore, System 1+ might induce more risk of enamel fracture.

Conclusions

1. The effect of the two adhesives on shear bond strength was significantly different ($P < 0.05$). Enlight could provide sufficient bond strength for plastic brackets, but System 1+ could not.
2. The effects of interaction of the two time intervals and the two bracket types on shear bond strength reached statistical significance ($P < 0.001$). This suggests that the bond strengths in the initial–plastic bracket subgroups were lower than those of the other combinations of time interval and bracket type.
3. The mode of bracket failure was at the bracket–adhesive interface in most specimens, except in the 24 hour metal bracket–System 1+ group.

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References

Akin-Nergiz N, Nergiz I, Behlfelt K, Platzer U 1996 Shear bond strength of a new polycarbonate bracket—an *in vitro* study with 14 adhesives. European Journal of Orthodontics 18: 295–301

Alkire R G, Bagby M D, Gladwin M A, Kim H 1997 Torsional creep of polycarbonate orthodontic brackets. Dental Materials 13: 2–6

Blalock K A, Powers J M 1995 Retention capacity of the bracket bases of new esthetic orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 107: 596–603

Bryant S, Retief D H, Russell C M, Denys F R 1987 Tensile bond strengths of orthodontic bonding resins and attachments to etched enamel. American Journal of Orthodontics and Dentofacial Orthopedics 92: 225–231

Buzzitta V A J, Hallgren S E, Powers J M 1982 Bond strength of orthodontic direct-bonding cement–bracket systems, as studied *in vitro*. American Journal of Orthodontics 81: 87–92

David V A, Staley R N, Bigelow H F, Jakobsen J R 2002 Remnant amount and cleanup for 3 adhesives after debracketing. American Journal of Orthodontics and Dentofacial Orthopedics 121: 291–296

Evans L J, Peters C, Flickinger C, Taloumis L, Dunn W 2002 A comparison of shear bond strengths of orthodontic brackets using various light sources, light guides, and cure times. American Journal of Orthodontics and Dentofacial Orthopedics 121: 510–515

Feldner J C, Sarkar N K, Sheridan J J, Lancaster D M 1994 *In vitro* torque-deformation characteristics of orthodontic polycarbonate brackets. American Journal of Orthodontics and Dentofacial Orthopedics 106: 265–272

Fernandez L, Canut J A 1999 *In vitro* comparison of the retention capacity of new aesthetic brackets. European Journal of Orthodontics 21: 71–77

Guan G *et al.* 2001 An approach to enhance the interface adhesion between an orthodontic plastic bracket and adhesive. European Journal of Orthodontics 23: 425–432

Harris A M P, Joseph V P, Rossouw P E 1992 Shear peel bond strengths of esthetic orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 102: 215–219

Liu J K, Chang L T, Chuang S F, Shieh D B 2002 Shear bond strengths of plastic brackets with a mechanical base. Angle Orthodontist 72: 141–145

Newman G V 1969 Adhesion and orthodontic plastic attachments. American Journal of Orthodontics 56: 573–588

Nkenke E, Hirschfelder U, Martus P, Eberhard H 1997 Evaluation of the bond strength of different bracket-bonding systems to bovine enamel. European Journal of Orthodontics 19: 259–270

Reynolds I R 1975 A review of direct orthodontic bonding. British Journal of Orthodontics 2: 171–178

Reynolds I R, von Fraunhofer J A 1977 Direct bonding in orthodontics: a comparison of attachments. British Journal of Orthodontics 4: 65–69

Sheen D H, Wang W N, Tarng T H 1993 Bond strength of younger and older permanent teeth with various etching time. Angle Orthodontist 63: 225–230

Sinha P K, Nanda R S 1997 Esthetic orthodontic appliances and bonding concerns for adults. Dental Clinics of North America 41: 89–109

Urabe H, Rossouw P E, Titley K C, Yamin C 1999 Combinations of etchants, composite resins, and bracket systems: an important choice in orthodontic bonding procedures. Angle Orthodontist 69: 267–275

Wang W N, Yeh C L, Fang B D, Sun K T, Arvystas M G 1994 Effect of H_3PO_4 concentration on bond strength. Angle Orthodontist 64: 377–382

Willems G, Carels C E L, Verbeke G 1997 *In vitro* peel/shear bond strength evaluation of orthodontic bracket base design. Journal of Dentistry 25: 271–278

Zarrinnia K, Eid N M, Kehoe M J 1995 The effect of different debonding techniques on the enamel surface. An *in vitro* qualitative study. American Journal of Orthodontics and Dentofacial Orthopedics 108: 284–293