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# *In vitro* comparison of the retention capacity of new aesthetic brackets

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SUMMARY Tensile bond strength and bond failure location were evaluated *in vitro* for two types of aesthetic brackets (non-silanated ceramic, polycarbonate) and one stainless steel bracket, using bovine teeth as the substrate and diacrylate resin as the adhesive.

The results show that metallic bracket had the highest bond strength (13.21 N) followed by the new plastic bracket (12.01 N), which does not require the use of a primer. The non-silanated ceramic bracket produced the lowest bond strength (8.88 N). Bond failures occurred mainly between bracket and cement, although a small percentage occurred between the enamel-cement interface with the metal and plastic brackets and within the cement for the plastic bracket. With the ceramic bracket all the failures occurred at the bracket-cement interface. This suggests that the problems of enamel lesions produced by this type of bracket may have been eliminated. The results also show that the enamel/adhesive bond is stronger than the adhesive/bracket bond in this *in vitro* study.

## Introduction

In recent years the aesthetics of the orthodontic appliance has become a topic of great interest with increasing numbers of adults receiving orthodontic treatment (Britton *et al.*, 1990).

The first step towards a more aesthetic orthodontic appliance was the introduction in 1965 of acid etching and the Bowen type resins which led to the substitution of metal bands by directly cemented brackets (Newman, 1965). Transparent or coloured brackets made of plastic (polycarbonate, a polymer) came into use at the beginning of the 1970s. These plastic brackets presented various problems which still remain unsolved, namely staining and colour changes due to their high capacity for absorbing water; the necessity of using compatible resins, intermediary conditioners or 'primers' for adhesion; poor dimensional stability resulting in inadequate archwire/slot control; and the high coefficient of friction due to the irregularity of their surface. Some manufacturers, in an attempt to solve these last two problems have incorporated a metal slot into the plastic bracket.

Ceramic brackets which were introduced into clinical practice at the end of the 1980s overcame the aesthetic limitations of the plastic brackets to some extent, being more durable and resistant to staining. Also torque may be readily expressed by these brackets. The ceramic brackets currently on the market are made of aluminium oxide ($Al_2O_3$) (Swartz, 1988) and may be divided into two groups, monocrystalline and polycrystalline brackets.

Ceramic brackets have been widely used, but various difficulties have emerged, including breakage, increased friction, wear of those teeth in contact with the brackets (which are harder than the tooth enamel) and damage to the enamel during removal. In order to reduce the risk of breakage, the brackets have a much more bulky design than metallic brackets. Øgaard and Rolla (1988), Viazis *et al.* (1989), Ghafari (1992), and Proffit (1992) have recommended that ceramic brackets should only be used on upper anterior teeth.

A further problem with ceramic brackets can occur during debonding. These brackets have mechanical and/or chemical union to the adhesive.

The chemical union (silanization) increases the adhesion capacity to sufficiently high levels to cause damage to the surface enamel (Swartz, 1988; Storm, 1990; Viazis *et al.*, 1990, 1993; Jeiroudi, 1991; Winchester, 1991) or fracture of the bracket (Britton *et al.*, 1990; Chaconas *et al.*, 1991) when they are removed. Viazis *et al.* (1993) and Swartz (1988) found that mechanically retained ceramic brackets did not present such problems in debonding. Viazis *et al.* (1990) and Winchester (1991) reported higher bond strength with silanized ceramic bases than with mechanical retention bases (Gwinnett, 1988; Britton *et al.*, 1990; Harris *et al.*, 1992; Blalock and Powers, 1995). The latest generation of ceramic brackets use mechanical retention which, on the evaluation of their bonding capacity, show results equivalent to metal brackets (Ødegaard and Segman, 1988; Harris *et al.*, 1992).

The bases of both metal and new plastic brackets rely on mechanical retention. The adhesive material flows into the grooves which form a fine grid over the back of the base of the bracket.

The aim of this research was to evaluate the bond strength of the bases of two aesthetic brackets, one plastic and the other ceramic, representing the latest generations of brackets, and to compare them with a metal bracket. This evaluation was carried out by measuring the tensile bond strength and site of fracture.

## Materials and methods

The types, retention systems, trade names, and manufacturers of the brackets used in this study are shown in Table 1.

The plastic bracket (SP) contains a new base that eliminates the need for a primer. The ceramic bracket (ALL) is composed of polycrystalline aluminium oxide. The metal bracket (M), as with the other two, has a base which facilitates mechanical retention.

The adhesive used was 80 per cent diacrylic Bis-GMA by weight and was self-cured (Concise 3M Unitek, California, USA)

Thirty lower incisors of Friesian cattle were used as the substrate.

The nominal area of the base of the brackets was measured with a computer with VIDS-V® (Synoptics Ltd, Cambridge Science Park, Cambridge, UK), a program which analyses digitized images of the bases. Five brackets, of each type, were selected at random and each one was measured five times.

The machine used for bond strength testing was an Instron (series number: 4411 H1959, Instron Ltd, England) equipped with a load cell with a sensitivity range of ±5000 N (Series number UK 149; Figure 1), connected to a compatible PC which analysed the data using the Series IX Automated Materials Testing System, Version 5 (Instron Ltd, High Wycombe, Bucks, UK).

A jig was constructed to support the bracket/adhesive/enamel complex (Figure 2). The cross-head speed was 0.5 mm per minute.

Cementation of the brackets to the substrate was always carried out by the same technician. The first step consisted of setting up the brackets in their jig with self-curing resin, keeping the base of the brackets and the base of the jig parallel. The surface of the enamel was then pumiced and etched for 60 seconds with a 37 per

**Table 1** Codes, types, method of retention, commercial names and manufacturers of brackets tested.

| Code | Type | Method of retention | Product | Manufacturer |
|---|---|---|---|---|
| SP | Plastic, metallic slot | Mechanical | Spirit MB® | Ormco Corporation (California, USA) |
| ALL | Polycrystalline ceramic | Mechanical | Allure IV® | G.A.C. Orthodontics Products (New York, USA) |
| M | Metallic | Mechanical | Mini Standard Edgewise® | American Orthodontics Corp. (Wisconsin, USA) |

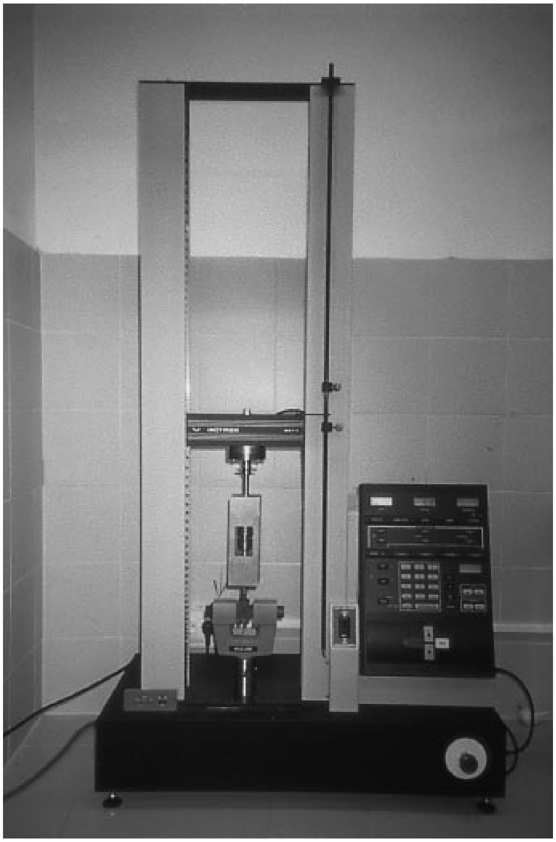

**Figure 1** Universal testing machine with the vertical traction system.

cent phosphoric acid solution, sprayed with water during a further 60 seconds and gently dried. The jig containing the bracket was then bonded to the tooth, using Concise (3M Unitek, Monrovia, California, USA). The samples were stored for 24 hours in deionized water at 37ºC in order to allow them to reach maximum adhesion (Blalock and Powers, 1995). A second jig was set up using a device which brought the bases of both jigs into parallel positions, ensuring an exact vertical distribution of force. Tensile testing was performed and the force at debond measured. Ten samples of each bracket-cement combination were prepared and tested making a total of 30 tests.

The fracture site was determined using the Adhesive Remnant Index, developed by Årtun and Bergland in 1984 (Table 2), using an optical microscope.

The data were checked for normality using the Kolmogrov–Smirnov non-parametric test and analysed using the ANOVA. The level of significance used throughout the statistical examination was 5 per cent ($P = 0.05$).

## Results

Table 3 shows the nominal area of the base and the mean tensile bond strength for each bracket.

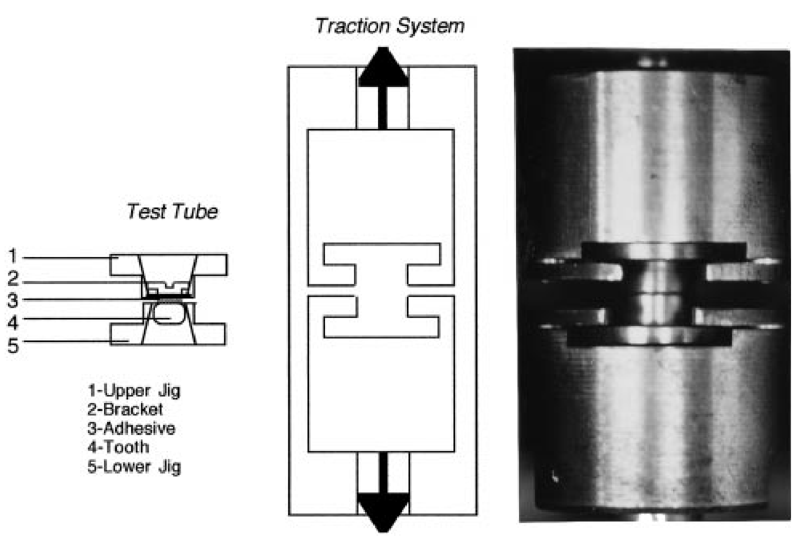


**Figure 2** Diagram and photograph of the traction system used in this test.

**Table 2** Modified Adhesive Remnant Index (ARI).

| Value | Criterion | Interpretation |
|---|---|---|
| 0 | No adhesive left on the tooth | Fracture at enamel-cement interface |
| 1 | Less than half of the adhesive left on the tooth | |
| 2 | More than half of the adhesive left on the tooth | Fracture at cement-bracket interface |
| 3 | All adhesive left on the tooth, with distinct impression of the bracket mesh | |
| 4 | Adhesive left on tooth and bracket base equally | Fracture within the cement |

**Table 3** Results for bond strength and (N) nominal area ($mm^2$).

| | Bracket | | |
|---|---|---|---|
| | ALL | M | SP |
| Area | 11.34 | 12.88 | 11.06 |
| Bond strength | 8.88 | 13.21 | 12.01 |
| SD | 0.87 | 0.47 | 0.77 |
| Min. | 7.59 | 12.52 | 10.89 |
| Max. | 10.01 | 14.00 | 13.01 |

**Table 4** Site of bond failure (%).

| | Bracket | | |
|---|---|---|---|
| | ALL | M | SP |
| Enamel-cement | 0 | 14 | 4 |
| Cement-bracket | 100 | 86 | 80 |
| Within cement | 0 | 0 | 16 |

Bracket M produced the highest bond strength mean (13.21 N), followed by SP (12.01 N), and ALL (8.88 N). Tukey's test determined significant difference ($P = 0.01$) between all the sets of brackets ALL-M, M-SP, and ALL-SP.

The location of fracture for each test sample indicates which point in the system is weakest. There are three possible locations in this experiment, within the body of the cement itself, at the enamel-cement union, and at the cement-bracket union.

Table 4 shows the distribution of fracture sites according to the bracket used. For the ALL bracket, all the fractures occurred at the cement-bracket union. Bracket M showed 86 per cent of breakage occurring at the cement-bracket union with the remaining 14 per cent at the enamel-cement union. With regard to the SP bracket 80 per cent of fractures were at the cement-bracket union, 16 per cent within the cement itself and 4 per cent at the enamel-cement union. Fracture of enamel-cement union was rare and associated with bracket M and SP, and fracture within the cement was associated only with bracket SP.

## Discussion

The results of this study must be considered with regard to:

1. The progressive increase of force and the type of force applied to the brackets under laboratory conditions is not representative of the forces which occur in clinical cases (Zachrisson, 1994). In the mouth the brackets are not only subjected to forces of tension, but also to shearing and twisting and to combinations of all of these. No experiments exist, either in the laboratory or in the clinic, which could constitute a valid measurement of each factor separately (Blalock and Powers, 1995).
2. The conditions in the oral cavity, with variations in temperature, humidity, acidity, the presence of plaque, and other stresses cannot be reproduced in the laboratory (Newman

*et al.*, 1994). Clinically, a higher failure rate may be observed in the enamel-cement interface than has been noted under laboratory conditions, because the ideal conditions for acid etching are much more difficult to achieve *in vivo*. Factors such as humidity, temperature, time, and patient mobility cannot be controlled in clinical tests.

In spite of all this, laboratory tests are necessary for the initial evaluation of adhesives and may provide background information for further clinical studies. However, for the reasons already stated, clinical testing may be extremely difficult to carry out and in some cases impossible, and when results are obtained these may be inconclusive due to the combination of uncontrollable factors.

The use of the metal bracket in this study serves as a control with which to compare the data obtained from the other types of bracket. The bond strength and behaviour during debonding remain closest to the ideal (Matasa, 1992).

In published literature into the adhesion of brackets to cement, three types of substrate have been used: human or cattle teeth and plastic cylinders. It can be difficult to find sufficient human teeth of the same type with intact enamel (i.e. without cavities or decalcifications), and which have been stored under equivalent conditions following extraction. Those human teeth which tend to retain the best preserved enamel are premolars extracted for orthodontic reasons, but it can be difficult to collect a sufficiently high number over a relatively short period of time. The use of plastic cylinders as a substrate restricts the examination of bonding systems to the cement-bracket union. Smith and Casko (1976) and Nakamichi *et al.* (1986) who carried out comparative studies of the adhesive capacity of resins and cements to the enamel of both human and bovine teeth did not find a significant difference, although the values were slightly lower in cattle thus justifying their use as a substrate for the testing of adhesive systems. These results together with the ability to study the failure of the bonding system at each interface and the relative ease with which results are obtained, render the use of bovine teeth a suitable alternative to either plastic or human teeth (Lopez, 1980; Ødegaard and Segman, 1988; Maskeroni *et al.*, 1990; Gaffey *et al.*, 1995; Sinha *et al.*, 1995; Trimpeneers *et al.*, 1996).

The control over ambient factors and the standardization of sample preparation reduce the experimental variability. This together with the fact that the range of sample quantities varied between 6 and 13 in other investigations (Buzzitta *et al.*, 1982; De Pulido and Powers, 1983; Viazis *et al.*, 1990; Winchester, 1991; Newman *et al.*, 1994) justify the number of samples used in this study.

The metal bracket M showed the maximum resistance to tension (13.21 N) followed by the plastic bracket SP (12.01 N) and the ceramic bracket ALL (8.88 N). These results differ from previous reports of bond strength of 6.9 N for bracket ALL and 10.3 N for SP (Blalock and Power, 1995). These differences may be attributable to the fact that in this study the latest generation brackets were studied as compared with those used by these researchers. These are the SP not requiring a primer and the ALL with mechanical retention; neither of which have been evaluated previously.

The differences found between the values obtained for bond strength when the area of the base is considered and those of other researchers (Blalock and Power, 1995), may be interpreted as a change in the manufacturing methods of the bases. It should be pointed out that the ceramic bracket show the lowest bond strength once silanization has been eliminated and the plastic bracket produces adequate bond strength in spite of not requiring a primer.

The results obtained in this study with regard to the most frequent fracture site agree with those found in other investigations (Lopez, 1980; Buzzitta *et al.*, 1982; De Pulido and Powers, 1983; Gwinnett, 1988; Ødegaard and and Segman, 1988; Britton *et al.*, 1990; Harris *et al.*, 1992; Gaffey *et al.*, 1995), and it has been established that acid etched enamel offers a higher retentive capacity than the bracket base and in some cases even greater than the capacity of the adhesive material itself. The differences between the results of the present study and those previously described may be due to the fact that the bond strength testing was in tension not shear or peel. The bracket ALL did not show any fracture at the interface with the enamel surface, which suggests the elimination of debonding problems previously associated with ceramic brackets.

## Conclusions

1. Bracket M showed the greatest resistance to debonding (13.21 N), followed by bracket SP (12.01 N) and, lastly, the ALL bracket (8.88 N).
2. The site of bond failure occurred primarily at the cement-bracket interface. Small percentages were found at the enamel-cement interface for bracket M (14 per cent) and SP (4 per cent). The occurrence of failure within the body of the cement itself was only to be found with the bracket SP (16 per cent). For bracket ALL all fractures occurred at the cement-bracket interface which may imply that the problem of enamel damage has been reduced. The results show that, under laboratory conditions, the enamel-adhesive bond strength is greater than the bracket-adhesive bond strength.

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