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Shear bond strength of a new dental adhesive used to bond brackets to unetched enamel

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SUMMARY The aims of the present study were to measure the shear bond strength of a new multipurpose dental adhesive, IntegraCem, for direct bonding of stainless steel and ceramic brackets to unetched enamel, and to determine the mode of bond failure. Both stainless steel and ceramic brackets (GAC) were bonded with IntegraCem to unetched extracted human premolars. After bonding, the teeth were either stored in a water bath at 37°C for 3 days or passed 2500 thermocycles from 6 to 60°C. Debonding was then performed with a shearing force using an Instron universal testing machine. The force was recorded at bond failure.

The results showed that the shear bond strength achieved was between 6.7 and 10.8 megapascals (MPa). Bond failure occurred at the enamel–adhesive interface, enabling more efficient enamel clean up. The shear bond strengths measured suggest that IntegraCem adhesive may be effectively used in orthodontic treatment.

Introduction

Bonding of orthodontic brackets has become an accepted clinical technique since 1970 (Zachrisson, 1994). Bonding has largely replaced banding and is superior to banding in terms of gingival and dental health, and aesthetics. The bonding procedure is based on enamel alteration created by acid etching of the enamel as developed by Buonocore (1955).

Since the 1970s new dental adhesives have been developed in an attempt to achieve high bond strength when bonding to etched enamel or dentine (Eliades *et al.*, 1990). Several generations of bonding materials developed for restorative purposes were later applied to orthodontics (Reynolds, 1975; Alexandre *et al.*, 1981; Miguel *et al.*, 1995). Recently, a new adhesive material IntegraCem (BJM Laboratories, Or-Yehuda, Israel) has been produced. IntegraCem, also known as High-Q-Bond, is a dentine-bonding agent, which belongs to the fourth generation of dental adhesives (Eppelbaum *et al.*, 1995). It is composed of acrylic monomer methylmethacrylate (MMA) crosslinked with a multifunctional agent (trymethylopropane-triacrylate), an adhesion promoter (glycidoxy-propyltromethoxysilane), a co-monomer-aliphatic polyester (urethane acrylate), and initiators for self-curing (dimethyl-*p*-toluidine and benzoyl peroxide). The IntegraCem composition also includes PolyMMA, inorganic fillers, and coupling agents. According to the manufacturer it provides high tensile bond strength and can be used for bonding to various substrates such as dentine, enamel, noble and base metal alloys, amalgam, composite, and porcelain. The efficacy of this adhesive in bonding orthodontic brackets to etched enamel, amalgam, and porcelain has recently been established (Gillis and Redlich, 1998; Harari *et al.*, 2000).

Debonding of brackets by clear separation without adhesive remanents on the teeth is important since removal of the residual resin may damage the enamel surface (Zarrinnia *et al.*, 1995). Thus, the location of bond failure is an important advantage of both procedure and bonding material. Indeed, bonding to unetched enamel, using glass ionomer cement, has been shown to result in less cement remaining on the enamel after debonding (Wiltshire, 1994). It was also found that the bond strength following bonding to unetched enamel, using resin-glass ionomer cements, was adequate for orthodontic purposes, although the shear bond strength (SBS) was lower than that found bonding to etched enamel (Voss *et al.*, 1993; Lippitz *et al.*, 1998).

According to the manufacturer of IntegraCem, this adhesive can be used to bond to unetched enamel in combination with the enamel-bonding agent Prima Bond 97 (BJM Laboratories), which forms an excellent dual bond to both the unetched enamel and the IntegraCem.

Therefore, the aims of this study were:

1. To measure the shear bond strength of IntegraCem in bonding orthodontic metal and ceramic brackets to unetched enamel.
2. To determine the mode of failure following debonding.

Materials and methods

Seventy-five non-carious human premolars were used in this study. The teeth were extracted for orthodontic reasons and stored for a maximum period of 3 months in saline solution until use. The apical half of the root was removed with a separating disk, and the cervical half was embedded in self-curing acrylic. The teeth were divided into five equal groups.

In group 1, standard edgewise stainless steel premolar brackets (0.022×0.028 inch) (GAC Orthodontic Products, New York, USA), which according to the maufacturer have a mesh base area of 0.115 cm^2, were directly bonded to the crowns of the teeth as follows. The enamel was polished with non-fluoride pumice, rinsed, and dried prior to bonding. The enamel bonding agent Prima Bond 97 was dispensed on a brush, then applied to the tooth and left undisturbed for 15 seconds, dried with a vigorous blast of air, and finally cured for 20 seconds with a visible light. IntegraCem was prepared for bonding according to the manufacturer's instructions (i.e. equal amounts of base and catalyst were dispensed onto a mixing pad and mixed for 20 seconds), applied to the bracket mesh, which was then placed on the prepared enamel. Excess adhesive was immediately removed from around the margins of the bracket. After bonding, the teeth were incubated in a saline solution at 37°C for 72 hours in order to permit final setting of the bonding material.

In group 2, similar brackets and bonding procedures were used. However, after incubation in saline solution at 37°C for 72 hours the teeth were thermocycled 2500 times between 6 and 60°C at a frequency of 1 cycle per minute to simulate accelerated ageing by thermally induced stress.

In group 3, ceramic brackets (Allure, GAC Orthodontic Products) with a base area of 0.126 cm^2 were bonded to unetched enamel using IntegraCem following application of Prima Bond 97. The teeth were incubated in a saline solution at 37°C for 72 hours.

In group 4, IntegraCem was compared with Fuji Ortho LC (GC Corporation, Tokyo, Japan), a bonding material known to bond brackets to unetched enamel. Thus, 15 stainless steel brackets were bonded to unetched enamel according to the manufacturer's instructions. Following bonding the teeth were incubated in a saline solution at 37°C for 72 hours.

In group 5, stainless steel premolar brackets were directly bonded to etched enamel using IntegraCem without Prima Bond 97. The teeth were polished with non-fluoride and oil-free pumice, rinsed, dried, and etched with 37 per cent phosphoric acid for 20 seconds, and again washed and dried before bonding. The teeth were incubated in a saline solution at 37°C for 72 hours.

The brackets were primarily debonded using shear loading with an Instron universal testing machine (Segensworth, Fareham, UK) and a shearing instrument (Bencor multi-T, testing device for dental restorative materials; Danville Engineering, San Ramon, CA, USA) (Figure 1). The crosshead speed was set at 0.5 mm/minute. The force was recorded at bond failure. The significance of the results was evaluated by a

Figure 1 The Instron testing machine with a shearing instrument (arrowhead) resting on a bracket bonded to the crown of the tooth (arrow).

Student's *t*-test. Following debonding the mode of failure was determined by visual examination of location of the residual bonding material.

Results

The SBS of the stainless steel brackets bonded to unetched enamel and stored in saline solution was 8.29 ± 3.56 MPa (Group 1, Table 1). When the teeth were thermocycled, the SBS decreased to 6.57 ± 2.04 MPa (Group 2, Table 1). The SBS of ceramic brackets bonded to unetched enamel and stored in saline solution was 8.08 ± 2.98 MPa (Group 3, Table 1), and for stainless steel brackets bonded with Fuji Ortho LC to unetched enamel and stored in saline solution it was 7.18 ± 3.70 MPa (Group 4, Table 1). No significant difference was found between any of the unetched groups.

The SBS measured in the acid-etched teeth was 10.86 ± 2.08 MPa (Group 5, Table 1), and was significantly higher than all the other unetched groups ($P < 0.05$).

The mode of failure of the different groups is presented in Table 2. In all the unetched groups, the failure occurred at the enamel–adhesive interface irrespective of the type of bracket, the bonding material, or the incubation conditions. In the etched group (Group 5) bond failure occurred at the adhesive–bracket interface.

Table 2 Location of bond failure in each group.

Group	Location of bond failure
1	enamel–adhesive interface
2	enamel–adhesive interface
3	enamel–adhesive interface
4	enamel–adhesive interface
5	adhesive–bracket interface

Discussion

Since Buonocore (1955) first described the acid-etch procedure, etching of enamel has been a prerequisite for successful bonding of orthodontic attachments. The present study, however, evaluated the efficacy of a new dental adhesive

Table 1 Shear bond strengths for the five different groups expressed in megaPascals.

Group	I	II	III	IV	V
Type of bracket	Stainless steel	Stainless steel	Ceramic	Stainless steel	Stainless steel
Enamel etching	No	No	No	No	Yes
Adhesive	IntegraCem	IntegraCem	IntegraCem	Fuji Ortho LC	IntegraCem
Incubation	37°C 72 hours	Thermocycling	37°C 72 hours	37°C 72 hours	37°C 72 hours
Shear bond strength (MPa)	8.29 ± 3.56	6.57 ± 2.04	8.08 ± 2.98	7.18 ± 3.70	10.86 ± 2.08 $P < 0.05$

in bonding of orthodontic brackets to unetched enamel. The results obtained show that the SBS of all the brackets bonded to unetched enamel was within the range of 6–10 MPa. This strength range is considered as optimal for successful bonding of brackets to enamel (Reynolds, 1975).

No significant difference was found between IntegraCem or Fuji Ortho LC in bonding stainless steel brackets to unetched enamel. The result of the present investigation with Fuji Ortho LC (7.18 ± 3.70) was higher than that reported by Lippitz *et al.* (1998) of 5.9 ± 2 MPa.

The lowest SBS was found in the thermocycled group, but this was still within the optimal range. Thermocycling produces ageing effects within the bonded system, similar to those occurring in the mouth during eating, drinking, etc. The effect of thermocycling on SBS is controversial. Smith *et al.* (1988) found no difference in SBS due to thermocycling, whereas Zachrisson *et al.* (1996) advocated thermocycling of experimentally bonding brackets due to reduction in SBS, as indeed occurred in the present investigation.

The SBS of etched enamel found in the present study is in accordance with a previous report, being significantly higher than the unetched (Wiltshire, 1994).

An important advantage of an adhesive is its ability to debond by clear separation from the tooth. The preferable situation would be that after removing the brackets the enamel surface remains clean from the adhesive. In the present study, only in the acid-etched group did separation occur between the bonding material and the brackets with the remnant of the adhesive remaining adhered to the enamel. In all the unetched groups the enamel remained clear of bonding material after debonding. Clinical evaluation of IntegraCem is currently being conducted.

Conclusions

1. Adequate SBS for orthodontic purposes was achieved when stainless steel or ceramic brackets were bonded with IntegraCem to unetched enamel.
2. The unetched enamel remained clear of residual material following debonding.

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