Resin-modified glass ionomer cements for bonding orthodontic retainers

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SUMMARY The aims of this study were to evaluate the shear bond strength (SBS), fracture mode, and wire pull out (WPO) resistance between resin-modified glass ionomer cement (RMGIC) and conventional orthodontic composite used as a lingual retainer adhesive. Forty lower human incisors were randomly divided into two equal groups. To determine the SBS, either Transbond-LR or Fuji Ortho-LC was applied to the lingual surface of the teeth by packing the material into cylindrical plastic matrices with an internal diameter of 2.34 mm and a height of 3 mm. To simulate the lingual retainer bonding area. To test WPO resistance, 20 samples were prepared for each composite where the wire was embedded in the composite material and cured, 20 seconds for Transbond-LR and 40 seconds for Fuji Ortho-LC. The ends of the wire were then drawn up and tensile stress was applied until failure of the resin. A Student’s t-test for independent variables was used to compare the SBS and WPO data. Fracture modes were analyzed using Pearson chi-square test. Significance was determined at P<0.05.

The SBS values were 24.7 ± 9.2 and 10.2 ± 5.5 MPa and the mean WPO values 19.8 ± 4.6 and 11.1 ± 5.7 N for Transbond-LR and Fuji Ortho-LC, respectively. Statistical analysis showed that the SBS and WPO values of Transbond-LR and Fuji Ortho-LC were significantly different (P < 0.001). No significant differences were present among the groups in terms of fracture mode. However, the RMGIC resulted in a significant decrease in SBS and WPO; it produced sufficient SBS values on the etched enamel surfaces, when used as a bonded orthodontic retainer adhesive.

Introduction

Direct bonded lingual retainers are the most commonly preferred retention devices (Bearn, 1995) as they result in less relapse in the long term (Oesterle et al., 2001). Besides various designs, their basic construction consists of a length of wire attached to the etched enamel with composite (Bearn, 1995). These composites include either conventional restorative or specific orthodontic bonding resins (Bearn, 1995).

Årtun (1984) investigated the potential caries and periodontal problems associated with long-term use of different types of bonded lingual retainers and concluded that, regardless of the type of wire involved in construction of the 3-3 retainers, there is a tendency for plaque and calculus to accumulate along the retainer wires, and for this tendency to increase with time. Plaque accumulation often promotes subsequent acid production leading to gingival problems, demineralization, and an alteration in the appearance of the enamel surface. In order to prevent demineralization or white spot lesions, research has focused mainly on protocols for fluoride intervention. The anticariogenic and remineralizing effects of long-acting fluoride release from conventional glass ionomer cements (GICs) can be predicted and there are also indications of a similar effect from resin-modified glass ionomer cements (RMGICs). The popularity of RMGICs has increased for direct bonding of orthodontic attachments (Kent et al., 1973; Hotz et al., 1977; Cook and Youngson, 1988; Jobalia et al., 1997; Komori and Ishikawa, 1997; Bishara et al., 1998a, 2000; Chung et al., 1999; Flores et al., 1999; Meehan et al., 1999; Shammaa et al., 1999; Graf and Jacobi, 2000; Owens and Miller, 2000; Sfondrini et al., 2001; Valente et al., 2002; Godoy-Bezerra et al., 2006). Light-activated RMGIC have the advantages of GICs and the mechanical and physical properties of composite resins (Godoy-Bezerra et al., 2006). Conventional GICs release fluoride, chemically bond to enamel (Kent et al., 1973; Hotz et al., 1977) and adhere to moist fields (Cook and Youngson, 1988).

Lower bond strengths compared with composite resins and higher bond strengths compared with GICs were reported for RMGICs in a number of studies (Jobalia et al., 1997; Komori and Ishikawa, 1997; Chung et al., 1999; Meehan et al., 1999; Shammaa et al., 1999; Owens and Miller, 2000; Sfondrini et al., 2001). In contrast, RMGIC applications following 37 per cent phosphoric acid etch show comparable results with conventional orthodontic composites (Bishara et al., 1998a, 2000; Flores et al., 1999; Godoy-Bezerra et al., 2006).

Lingual retainer fabrication requires meticulous work and the clinician often encounters problems with regard to isolation. The advantages of bonding to moist enamel surfaces and fluoride release are thought to be favourable properties of RMGICs in lingual retainer fabrication. No studies in the literature appear to have evaluated RMGICs as lingual retainer adhesives. The aim of this in vitro
study was to evaluate a conventional lingual retainer adhesive (Transbond-LR) and a widely used RMGIC (Fuji Ortho-LC) by means of shear bond strength (SBS) and wire pull out (WPO) tests.

For the purposes of this study, the null hypotheses assumed that there were no statistically significant differences in (1) bond strength, (2) failure site location, and (3) WPO values of materials bonded to enamel with RMGIC and a conventional lingual retainer adhesive system.

Materials and method

Bonding procedure

Forty freshly extracted human mandibular incisor teeth were used in this part of the study. Ethical approval for this research was obtained from the regional committee of Erciyes University. Teeth with hypoplastic areas, cracks, or irregularities of the enamel structure were excluded. The criteria for tooth selection dictated no pre-treatment with chemical agents such as alcohol, formalin, or hydrogen peroxide. The extracted teeth were stored in distilled water until use (maximum 1 month). The water was changed weekly to avoid bacterial growth. Callus and debris were removed with a scaler and the teeth were pumiced. The teeth were moulded in square acrylic blocks with the long axis perpendicular to the upper surface of the blocks. A 37 per cent phosphoric acid gel (3M Dental Products, St Paul, Minnesota, USA) was used for etching. Acid etching was performed for 15 seconds and washed for an additional 30 seconds. The enamel surface was dried with oil-free air until a frosty white appearance of the etched enamel was observed.

All bonding procedures were performed according to the manufacturer’s instructions by one author (AB). In group I, Transbond XT Primer (3M Unitek, Monrovia, California, USA) was applied, while in group II, the etched enamel was wiped with cotton pellets in order to create a moist surface prior to application of the RMGIC. No primer or conditioners were used.

Transbond-LR (group I; 3M Unitek) and RMGIC (group II; Fuji Ortho-LC, GC Company, Tokyo, Japan) were added to the lingual surface by packing the material into cylindrical shaped plastic matrices with an internal diameter of 2.34 mm and a height of 3 mm (Ultradent, South Jordan, Utah, USA; Figure 1). Group I was considered as the control for group II. The adhesives were cured with a quartz tungsten halogen light source (Hilux 350, Express Dental Products, Toronto, Ontario, Canada). The curing times were 20 seconds for Transbond-LR and 40 seconds for Fuji Ortho-LC.

SBS testing

For SBS testing, the specimens were mounted in a universal testing machine (Hounsfield Test Equipment, Salford, Lancashire, UK). A notch-shaped apparatus (Ultradent) attached to a compression load cell at a crosshead speed of 0.5 mm/minute was applied to each specimen at the interface between the tooth and composite until failure occurred. The maximum load (N) was divided by the cross-sectional area of the bonded adhesive posts to determine bond strength in megapascals.

Fracture analysis

Fracture analyses were performed using an optical stereomicroscope at ×20 magnification (SZ 40, Olympus, Tokyo, Japan). The amount of adhesive remaining on the enamel surface was coded by one investigator (TU) who was blinded to group allocations. Failures were classified as cohesive if more than 80 per cent of the resin remained on the tooth surface, adhesive if less than 20 per cent of the resin remained on the tooth surface, or mixed if certain areas exhibited cohesive fractures and others adhesive fractures.

WPO testing

In order to perform the WPO test, 40 acrylic blocks, with a diameter of 25 mm and a height of 10 mm, were prepared in moulds. In each block, a hole, 4 mm in diameter and 3 mm
in height, was drilled and a slot 0.6 mm wide and 1 mm deep was cut. Inclusion of the hole resulted in a clinically similar composite thickness and width, while the slot permitted the application of a standard 1 mm composite thickness over the wire. Similar to SBS testing, group I was prepared with Transbond-LR and group II with RMGIC.

Multistranded PentaOne® wire (Masel Orthodontics, Bristol, Pennsylvania, USA) 0.0215 inches in diameter was used in both groups. The wires were cut into 10 mm lengths. After insertion of the wires into the prepared slots, different resins were placed in the hole and cured. The curing was the same as for SBS testing.

The free ends of the wire were drawn up and bent with an orthodontic plier (Figure 2). The attachment arm of the tensile load cell of the universal testing machine was secured and the force applied at a crosshead speed of 0.5 mm/minute through the long axis of each sample. Data were recorded when the wires were pulled out from the resin.

Statistical analysis

All statistical analyses were performed with the Statistical Package for Social Sciences, version 13.0 for Windows 13.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics, including the mean, standard deviation, minimum, and maximum values, were calculated for the two groups. The normality test of Shapiro–Wilk and Levene’s variance homogeneity test were applied to the bond strength data. The data were normally distributed, and there was homogeneity of variance between the groups. A Student’s t-test for two independent variables was used to compare the SBS and WPO data of the two investigated adhesives. Fracture modes were analyzed using a Pearson chi-square test. Significance was predetermined at $P < 0.05$.

Results

Descriptive statistics and the results of the SBS testing are presented in Table 1. The Student’s t-test revealed statistically significant differences in bond strength between the groups ($P < 0.001$). Thus, the first null hypothesis was rejected. Group I (24.7 ± 9.2 MPa) showed significantly higher scores compared with group II (10.2 ± 5.5 MPa).

The fracture patterns of the specimens are shown in Table 2. In general, a greater percentage of the fractures were adhesive at the tooth–composite interface (60 per cent in group I and 55 per cent in group II). There were no statistically significant differences between the groups ($\chi^2 = 0.110$). Therefore, the second null hypothesis of this study failed to be rejected ($P = 0.946$).

Descriptive statistics and the results of WPO testing are shown in Table 3. For pull out scores, there were significant differences between the groups ($P < 0.001$). The mean WPO forces for group I (19.8 ± 4.6 N) were higher than in group II (11.1 ± 5.7 N). The third null hypothesis was thus rejected.

Discussion

Bonded retainers with flexible spiral wires have been proposed for long-term retention (Zachrisson, 1977) and different wire and adhesive combinations have been mentioned (Bearn, 1995; Bearn et al., 1997). Failure of a retainer bond results in a loss of retainer function and may,
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if ignored, lead to relapse (Radlanski et al., 2004). The most common failure type has been shown to be detachment at wire–composite interface (Bearn, 1995), but compound type failures are also described (Orsborn, 1983; Wasserman and Brezniak, 1998). According to a review on lingual retainers (Bearn, 1995), the most appropriate materials for bonded lingual retainers have received little attention and studies are required for optimum wire–composite combinations.

The aim of this in vitro study was to evaluate RMGICs as an alternative for bonding lingual retainers. These materials are widely used in dentistry and orthodontics. They have higher adhesive properties compared with conventional GICs, can absorb or release fluoride (Newman et al., 2001), and bond to moist environments eliminating the need to keep the teeth dry during bonding (Silverman et al., 1995). These properties are advantageous for lingual retainer fabrication which is a technique-sensitive procedure and requires isolation, especially in the lower anterior segment. As lingual retainers are exposed to the oral cavity and are intended to serve in the mouth for a long period of time, fluoride release and uptake is thought to reduce the risk of decalcification.

Fuji Ortho-LC, which was the RMGIC of choice, is widely used and commercially available. Although bonding to moist enamel is possible with RMGIC, etching was performed because according to the manufacturer, when a higher bond strength is needed, conventional etching can be performed. In addition, the bond strength of RMGICs has been shown to be reduced by one-third to one-half without acid etching (Bishara et al., 1998a). When maximum bond strength is needed and if water or saliva contamination is expected, Bishara et al. (1998a) advocated enamel surface treatment with 37 per cent phosphoric acid or 10 per cent polyacrylic acid. This can be the case particularly for lower bonded retainers. Phosphoric acid at a concentration of 37 per cent is preferred because etching with this concentration is shown to result in a comparable SBS to conventional orthodontic composites (Kent et al., 1973; Hotz et al., 1977; Cook and Youngson, 1988; Jobalia et al., 1997; Komori and Ishikawa, 1997; Bishara et al., 1998a, 2000; Chung et al., 1999; Flores et al., 1999; Meehan et al., 1999; Shammaa et al., 1999; Graf and Jacobi, 2000; Owens and Miller, 2000; Sfondrini et al., 2001; Valente et al., 2002; Godoy-Bezerra et al., 2006). Furthermore, enamel etching is necessary if a strong bond is required (Silverman et al., 1995).

In the present study, a statistically significant difference was found between the SBS values of the two adhesives tested. Fuji Ortho-LC specimens showed less favourable values compared with Transbond-LR. According to Reynolds (1979), adequate bond strength for clinical orthodontic needs varies between 5.9 and 7.8 MPa. In the present study, as the mean SBS value was 10.2 ± 5.5 MPa for group II, it is considered that Fuji Ortho-LC exhibited clinically acceptable SBS values. On the other hand, Schulz et al. (1985) related bond strength to the orthodontic force needed to move teeth in bone and suggested that an embedded wire or bracket should withstand forces of 0.5–4 N. The present results for both adhesives showed higher values than 0.5–4 N. However, clinical conditions may differ significantly in vivo. The present research was an in vitro study and the test conditions were not subjected to the rigours of the oral environment (Bishara et al., 1998b). Heat and humidity conditions in the oral cavity are highly variable. Because of the differences between in vivo and in vitro conditions as well as the testing method, a direct comparison cannot be made with the findings of other studies.

Most orthodontic bonding studies have shown a mix or cohesive-type failure (Årtun and Bergland, 1984; Oliver, 1988). In those studies, after bond strength testing, a part of the composite resin remained on either the enamel surface or the bracket base, causing cohesive rather than adhesive failure between the enamel and composite resin. Because brackets were not used in the present study, more adhesive failures occurred and the actual bond strength between the enamel and composite could be measured. Similar to previous findings (Demir et al., 2005; Malkoc et al., 2005), it was considered that the higher percentage of adhesive failures confirmed the accuracy of the bond strength method.

The study design was adopted from the research of Bearn et al. (1997). The composite thickness over the wire was 1 mm as greater amounts of composite produce relatively small increases in detachment forces and offer little clinical benefit (Bearn et al., 1997). This design was used to evaluate mean detachment forces both for Transbond-LR and Fuji Ortho-LC and these forces were interpreted as resistance to failure. The mean detachment values for Transbond-LR (19.8 ± 4.6 N) were higher than for Fuji Ortho-LC (11.1 ± 5.7 N) and the difference between the groups were statistically significant. Bearn et al. (1997) who compared six different composite resins, which were proposed as lingual retainer adhesives, via WPO tests reported scores of between 11.2 and 24.4 N. Transbond-LR in the present study showed higher detachment forces than those found by Bearn et al. (1997) with one exception, Concise with a detachment force of 24.4 N. On the other hand, Fuji Ortho-LC showed lower forces compared with the findings of Bearn et al. (1997). One major concern in this comparison is that increasing the wire diameter from 0.0175 to 0.0215 mm as greater amounts of composite produce relatively small increases in detachment forces and offer little clinical benefit (Bearn et al., 1997). Different from Bearn et al. (1997), PentaOne 0.0215 inch wire was used in this study. It can be assumed that samples prepared with Fuji Ortho-LC could result in lower WPO forces if 0.0175 inch wire–composite interface (Bearn, 1995), but compound type failures are also described (Orsborn, 1983; Wasserman and Brezniak, 1998). According to a review on lingual retainers (Bearn, 1995), the most appropriate materials for bonded lingual retainers have received little attention and studies are required for optimum wire–composite combinations.

The findings of this laboratory study may also encourage manufacturers to develop improved materials which at present are often marketed without adequate laboratory testing. With rapid advances in dental materials, newly developed products may overcome the shortcomings of RMGICs.
Conclusion
The RMGIC tested in this study resulted in lower bond strength values to etched enamel when compared with conventional lingual retainer adhesive but demonstrated SBs which were within the range previously suggested for clinical acceptability.

There was no evidence to suggest a statistical difference between the failure characteristics of the groups.

RMGIC presented statistically lower WPO resistance values compared with the control composite, i.e. Transbond-LR.

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