Resin-modified glass ionomer cements for bonding orthodontic retainers

Asli Baysal and Tancan Uysal

Department of Orthodontics, Faculty of Dentistry, University of Erciyes, Kayseri, Turkey

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 (Ultradent) 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 anti-cariogenic 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
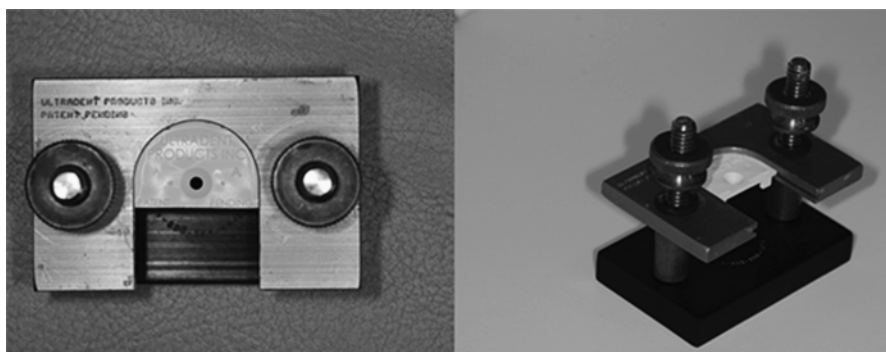

Figure 1 Apparatus for testing materials on the enamel surface.

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.
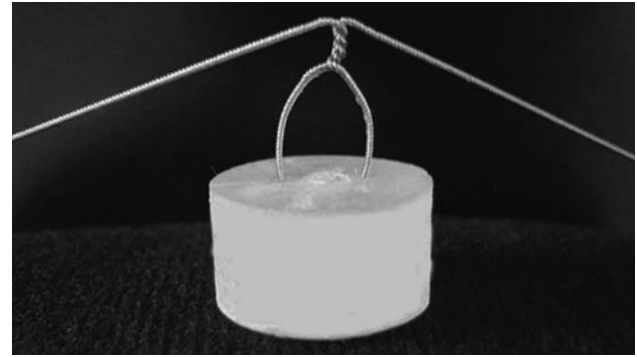

Figure 2　Prepared block for wire pull out resistance test.

Table 1　Descriptive statistics and results of the *t*-test, comparing shear bond strength of the two groups tested.

Groups	n	Shear bond strength (MPa)				Significance
		Mean	SD	Minimum	Maximum	
Transbond-LR	20	24.7	9.2	11.6	44.2	***
Fuji Ortho-LC	20	10.2	5.5	2.3	23.2	

***$P < 0.001$.

Table 2　Modes of failure after shear bond testing.

Groups	n	Failures			Significance
		Adhesive	Cohesive	Mix	
Transbond-LR	20	12 (60%)	1 (5%)	7 (35%)	NS
Fuji Ortho-LC	20	11 (55%)	1 (5%)	8 (40%)	

NS, not significant.

Table 3　Descriptive statistics and the results of *t*-test, comparing wire pull out (WPO) values of two groups tested.

Groups	n	WPO test (N)				Significance
		Mean	SD	Minimum	Maximum	
Transbond-LR	20	19.8	4.6	11.0	29.0	***
Fuji Ortho-LC	20	11.1	5.7	4.0	25.0	

***$P < 0.001$.

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,

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; Wasserstein 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 inches for PentaOne wire statistically increased the detachment force (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 PentaOne wire had been used.

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 SBSs 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.

Address for correspondence

Dr Tancan Uysal
Erciyes Üniversitesi
Dişhekimliği Fakültesi
Ortodonti A.D.
Melikgazi
Kampüs Kayseri 38039
Turkey
E-mail: tancanuysal@yahoo.com

References

Årtun J 1984 Caries and periodontal reactions associated with long-term use of different types of bonded lingual retainers. American Journal of Orthodontics 86: 112–118

Årtun J, Bergland S 1984 Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. American Journal of Orthodontics 85: 333–340

Bearn R 1995 Bonded orthodontic retainers: a review. American Journal of Orthodontics and Dentofacial Orthopedics 108: 207–213

Bearn D R, McCabe J F, Gordon P H, Aird J C 1997 Bonded orthodontic retainers: the wire-composite interface. American Journal of Orthodontics and Dentofacial Orthopedics 111: 67–74

Bishara S E, Olsen M E, Damon P, Jakobsen J R 1998a Evaluation of a new light-cured orthodontic bonding adhesive. American Journal of Orthodontics and Dentofacial Orthopedics 114: 80–87

Bishara S E, VonWald L, Zamtua J, Damon P L 1998b Effects of various methods of chlorhexidine application on shear bond strength. American Journal of Orthodontics and Dentofacial Orthopedics 114: 150–153

Bishara S E, VonWald L, Laffoon J F, Jakobsen J R 2000 Effect of altering the type of enamel conditioner on the shear bond strength of a resin-reinforced glass ionomer adhesive. American Journal of Orthodontics and Dentofacial Orthopedics 118: 288–294

Chung C H, Cuozzo P T, Mante F K 1999 Shear bond strength of a resin-reinforced glass ionomer cement: an *in vitro* comparative study. American Journal of Orthodontics and Dentofacial Orthopedics 115: 52–54

Cook P A, Youngson C C 1988 An *in vitro* study of the bond strength of a glass ionomer cement in the direct bonding of orthodontic brackets. British Journal of Orthodontics 15: 247–253

Demir A, Malkoc S, Sengun A, Koyuturk A E, Sener Y 2005 Effects of chlorhexidine and povidone-iodine mouth rinses on the bond strength of an orthodontic composite. Angle Orthodontist 75: 392–396

Flores A R, Sae'z G, Barcelo F 1999 Metallic bracket to enamel bonding with a photopolymerizable resin-reinforced glass ionomer. American Journal of Orthodontics and Dentofacial Orthopedics 116: 514–517

Godoy-Bezerra J, Vieira S, Oliveria J H G, Lara F 2006 Shear bond strength of resin-modified glass ionomer cement with saliva present and different enamel pretreatments. Angle Orthodontist 76: 470–474

Graf I, Jacobi B E 2000 Bond strength of various fluoride-releasing orthodontic bonding systems. Journal of Orofacial Orthopedics 61: 191–198

Hotz P, McClean J W, Sced I, Wilson A D 1977 The bonding of glass ionomer cements to metal and tooth substrates. British Dental Journal 142: 41–47

Jobalia S B, Valente R M, de Rijk W G, BeGole E A, Evans C A 1997 Bond strength of visible light-cured glass ionomer orthodontic cement. American Journal of Orthodontics and Dentofacial Orthopedics 112: 205–208

Kent B E, Lewis G G, Wilson A D 1973 The properties of a glass ionomer cement. British Dental Journal 135: 322–326

Komori A, Ishikawa H 1997 Evaluation of a resin-reinforced glass ionomer cement for use as an orthodontic bonding agent. Angle Orthodontist 67: 189–196

Malkoc S, Demir A, Sengun A, Ozer F 2005 The effect on shear bond strength of different antimicrobial agents after acid etching. European Journal of Orthodontics 27: 484–488

Meehan M P, Foley T F, Mamandras A 1999 A comparison of the shear bond strengths of two glass ionomer cements. American Journal of Orthodontics and Dentofacial Orthopedics 115: 125–132

Newman G V, Newman R A, Sengupta A K 2001 Comparative assessment of light-cured resin-modified glass ionomer and composite resin adhesives: *in vitro* study of a new adhesive system. American Journal of Orthodontics and Dentofacial Orthopedics 119: 256–262

Oesterle L, Shellhart C, Henderson S 2001 Enhancing wire-composite bond strength of bonded retainers with wire surface treatment. American Journal of Orthodontics and Dentofacial Orthopedics 119: 625–631

Oliver R G 1988 The effect of different methods of bracket removal on the amount of residual adhesive. American Journal of Orthodontics and Dentofacial Orthopedics 93: 196–200

Orsborn D B 1983 Bonded lingual retainers. American Journal of Orthodontics 83: 218–220

Owens S E, Miller B H 2000 A comparison of shear bond strengths of three visible light-cured orthodontic adhesives. Angle Orthodontist 70: 352–356

Radlanski R J, Natalie D, Zain N D 2004 Stability of the bonded lingual wire retainer—a study of the initial bond strength. Journal of Orofacial Orthopedics 65: 321–335

Reynolds I R 1979 A review of direct orthodontic bonding. British Journal of Orthodontics 2: 171–178

Schulz R P, Mayhew R B, Oesterle L J, Pierson W P 1985 Bond strengths of three resin systems used with brackets and embedded wire attachments. American Journal of Orthodontics 87: 75–80

Sfondrini M F, Cacciafesta V, Pistorio A, Sfondrini G 2001 Effects of conventional and high-intensity light-curing on enamel shear bond strength of composite resin and resin-modified glass ionomer. American Journal of Orthodontics and Dentofacial Orthopedics 119: 30–35

Shammaa I *et al.* 1999 Comparison of bracket debonding force between two conventional resin adhesives and a resin-reinforced glass ionomer cement: an *in vitro* and *in vivo* study. Angle Orthodontist 69: 463–469

Silverman E, Cohen M, Demke R, Silverman M 1995 A new light-cured glass ionomer cement that bonds brackets to teeth without etching in the presence of saliva. American Journal of Orthodontics and Dentofacial Orthopedics 108: 231–236

Valente R M, Rijk W G, Drummond J L, Evans C A 2002 Etching conditions for resin-modified glass ionomer cement for orthodontic brackets. American Journal of Orthodontics and Dentofacial Orthopedics 121: 516–520

Wasserstein A, Brezniak N 1998 Use of disclosing material to detect fixed retainer bond failures. Journal of Clinical Orthodontics 32: 598–599

Zachrisson B U 1977 Clinical experience with direct-bonded orthodontic retainers. American Journal of Orthodontics 71: 440–448