Attachment Bond Strengths of Thermoplastic Retainer Materials Using Two Acrylic Bonding Resins

RYAN PENDLETON, DDS
DANIEL RINCHUSE, DMD, MS, MDS, PHD
JANET M. ROBISON, PHD, DMD, MDS
JOHN M. CLOSE, MA, PMSD
ROY MARANGONI, MS, PHD

Thermoplastic retainers are now widely used in orthodontics for a variety of purposes, including active tooth movement.[1,2] Some thermoplastic materials allow the bonding of attachments to accommodate elastics or other such devices. Elastics can be connected to the retainer in one of two ways: they can be inserted through slits cut into the material,[2] or they can be placed on attachments bonded to the retainer (Fig. 1).

Thermoplastic retainers that permit bonding of attachments include Essix types A+ and ACE,* which are made of copolyester; GAC's NeoForm** sheets; and Glenroe's DuraClear*** material. In one reported case, a finger spring was attached to a full-coverage Essix appliance with cold-cure acrylic (polymethyl methacrylate) and adapted to a malpositioned incisor. Activation of the spring moved the tooth, with the retainer serving as the anchorage unit.[3] Other types of attachments that can be used to help move teeth or enhance anchorage include brackets, hooks, expansion screws, and acrylic alone.[3]

Attachments are usually bonded to thermoplastic retainers using either self-curing (cold-cure) or light-cured acrylic resin. Cold-cure acrylic comes as a separate liquid (monomer) and powder (polymer); when these are combined, the exothermic reaction produces a strong, durable acrylic

*Raintree Essix, Inc., 4001 Division St., Metairie, LA 70002; www.essix.com. A+ is a registered trademark; ACE is a trademark.

**Trademark of GAC International, Inc., 355 Knickerbocker Ave., Bohemia, NY 11716; www.gacintl.com.

***Glenroe Technologies, 1912 44th Ave. East, Bradenton, FL 34203; www.glenroe.com.

Dr. Pendleton

Dr. Rinchuse

Dr. Robison

Mr. Close

Dr. Marangoni

Dr. Pendleton is in the private practice of orthodontics at 1600 W. Gonzales Road, Suite C, Oxnard, CA 93036; e-mail: rye2112@yahoo.com. Dr. Rinchuse is a Clinical Professor of Orthodontics, Dr. Robison is a Clinical Assistant Professor of Orthodontics, and Mr. Close is an Assistant Professor of Dental Public Health and Information Management, University of Pittsburgh School of Dental Medicine, Pittsburgh, PA. Dr. Marangoni is a Faculty Emeritus, Department of Mechanical Engineering and Materials Science, University of Pittsburgh.

material (PMMA).[4] Triad**** visible-light-polymerized (VLP) resin is composed of a matrix of urethane dimethacrylate plus small amounts of microfine silica to control its elastic properties.[5] Although cold-cure and light-cured resin materials have been compared in a few studies of denture base repairs, with mixed results,[5,6] we found no previous comparative tests involving acrylic-bonded attachments to thermoplastic materials. Therefore, the present study was devised to compare the strength of bonded attachments among different thermoplastic materials using the two types of acrylic resin.

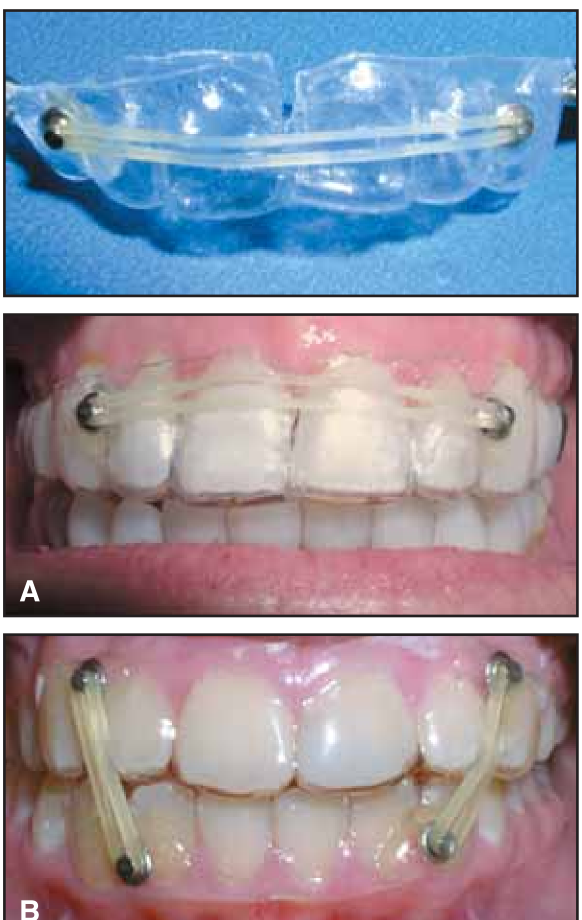

Fig. 1 A. Metal buttons attached to thermoplastic aligner for placement of intra-arch elastic to close diastema (aligner was sectioned between maxillary central incisors). B. Buttons attached to thermoplastic aligners at canines in both arches for placement of vertical elastics to correct anterior open bite.

Materials and Methods

A retainer was fabricated from each of the four ethylene vinyl acetate (EVA) thermoplastic materials selected for this study: Essix types A+ and ACE, GAC's NeoForm, and Glenroe's DuraClear sheets. The retainers were fabricated using a BioStar† machine according to each manufacturer's instructions and were adapted to a Dentoform typodont†† to simulate in vivo conditions as closely as possible.

The maxillary arch of each typodont was placed in the BioStar machine, and the thermoplastic material was adapted and allowed to cool. The material was then trimmed on the buccal surface to the base of the typodont. Full palatal coverage was provided on the lingual surface to ensure mechanical retention; distally, the retainer cov-

****Registered trademark of Dentsply International, 221 W. Philadelphia St., P.O. Box 872, York, PA 17405; www.dentsply.com.

†Registered trademark of Great Lakes Orthodontics, Ltd., 200 Cooper Ave., Tonawanda, NY 14151; www.greatlakesortho.com.

††Registered trademark of Columbia Dentoform, 34-24 Hunters Point Ave., Long Island City, NY 11101; www.columbiadentoform.com.

Fig. 2 Thermoplastic retainer with bonded attachments on typodont.

ered the distobuccal and distolingual cusps of the second molars.

After trimming, the retainer was left on the typodont (Fig. 2) and prepared for bonding by roughening the attachment surfaces with a high-speed drill and a finely fluted finishing bur. Fourteen universal attachments, each featuring an eyelet soldered to a conventional metal base, were bonded to each retainer, one on the buccal surface of each tooth from second molar to second molar. Half of the arch (second molar to central incisor) had eyelets bonded with Caulk's orthodontic resin,‡ a cold-cure acrylic; the other half was bonded with Triad VLP resin.

For the eyelets bonded with cold-cure acrylic, the liquid monomer was placed on the roughened attachment areas. After two minutes, a second layer of monomer was applied to the bonding surfaces. Small amounts of powder and liquid were then mixed to a syrup-like consistency, and this material was applied to the metal base of each eyelet, which was carefully positioned on the thermoplastic material. The remaining acrylic was placed over the entire buccal surface of the base and around the eyelet, avoiding the eyelet loop. The retainer was allowed to dry for 24 hours.

A similar procedure was followed for the Triad VLP resin. The acrylic monomer was placed on the roughened areas, and after two minutes, a second layer was applied to the bonding surfaces. The Triad VLP material was then placed on the base of each eyelet, the eyelet was positioned on the retainer, and the remaining acrylic was placed over the buccal surface of the attachment base. After 30 seconds of curing with a conventional light unit, the retainer was allowed to dry for 24 hours.

An Instron‡‡ machine was used to measure the amount of force required to remove each attachment from its retainer. The typodont was fastened to the base of the machine using a stiff clamp over the palatal area, and an .018" stainless steel wire was threaded through the eyelet. The ends of the wire were held together by the superior lever arm of the Instron machine, which applied a constant shear force to the attachment by moving occlusally at a rate of .5" per second.

The Instron machine generated a graph representing the force applied to the retainer over time, from which the maximum detachment force (MDF) for each attachment was extrapolated. Statistical analysis was conducted using a two-way (acrylic type) by four-way (retainer type) analysis of variance. The level of statistical significance was set at $p = .05$.

Results

Statistically significant differences were found among retainer types using Triad VLP resin ($p \leq .0004$), but not the cold-cure acrylic ($p = .291$, Table 1). When all independent variables were compared, the highest bond strength was exhibited by

TABLE 1
MEAN MAXIMUM DETACHMENT FORCE (MDF) OF VARIOUS RETAINER/RESIN COMBINATIONS (OUNCES)

Retainer Type	Resin Type	N	MDF	SD
ACE	Caulk	7	189.84	41.26
	Triad VLP	7	199.64	62.85
	Total	14	194.74	51.33
NeoForm	Caulk	7	212.15	99.00
	Triad VLP	7	229.24	92.62
	Total	14	220.69	92.53
A+	Caulk	7	207.65	85.16
	Triad VLP	7	100.66	34.99
	Total	14	154.15	83.63
DuraClear	Caulk	7	264.77	57.28
	Triad VLP	7	54.13	12.43
	Total	14	159.45	116.32
Total	Caulk	28	218.60	75.54
	Triad VLP	28	145.92	91.40
	Total	56	182.26	90.81

‡Caulk, 38 W. Clark Ave., Milford, DE 19963; www.caulk.com.

‡‡Instron, 825 University Ave., Norwood, MA 02062; www.instron.com.

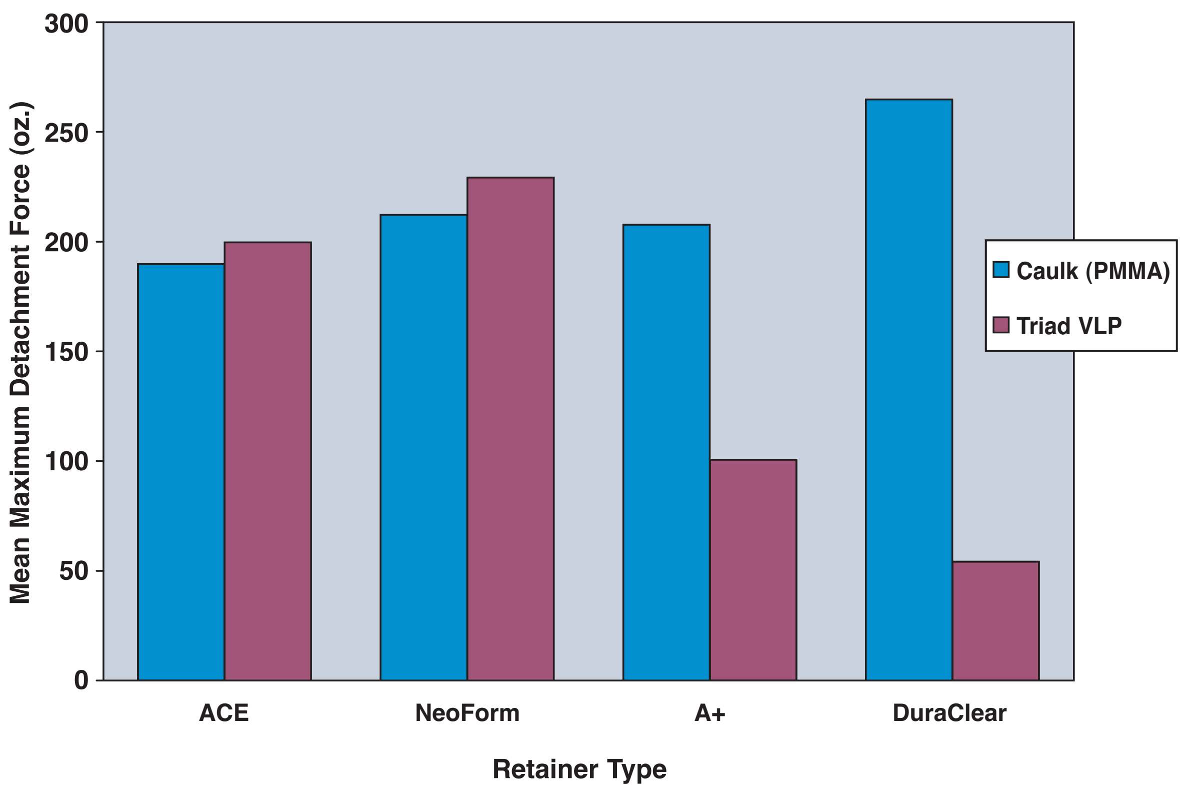

Fig. 3 Mean maximum detachment forces of various retainer and resin types.

the DuraClear material and cold-cure acrylic, while the lowest bond strength was found with the DuraClear and Triad VLP (Fig. 3). The NeoForm retainer material showed the best overall performance when the results for both resin types were combined.

Post hoc analysis using Fisher's least-significant-difference test revealed significant differences among the ACE and A+ ($p = .004$), ACE and DuraClear ($p \leq .004$), NeoForm and A+ ($p \leq .0004$), and NeoForm and DuraClear ($p \leq .0004$) materials using Triad VLP. Comparison of the two resin types for each retainer type showed statistically significant differences for the A+ ($p = .010$) and DuraClear ($p \leq .0004$) materials, but no significant differences for the ACE ($p = .736$) and NeoForm ($p = .744$) materials. Greenhouse-Geisser tests performed for resin types ($\beta = .962$) and retainer types ($\beta = .982$) found the sample sizes adequate to predict significant effects.

Discussion

The results of this study indicate that, overall, attachments bonded to the tested thermoplastic materials with cold-cure acrylic are more durable than those bonded with Triad VLP. For the ACE and NeoForm materials, the attachment bond strength was slightly greater with Triad VLP than with cold-cure acrylic, but the differences were not statistically significant. Bond strengths with Triad VLP were significantly less than those with cold-cure acrylic for the DuraClear and A+ retainers.

This study has several potential limitations.

First, the sample size was small, although it was found to be adequate to determine significant differences. The inclusion of more attachment methods and retainer types would have bolstered the results. In addition, the use of metal or even plastic hooks or buttons, rather than metal eyelets, might have made the study more clinically relevant. Moreover, an elastic is more likely to be used in vivo than the wire used to remove the attachments, which was selected for this test because of its rigidity.

The most significant limitation of the study, however, is that it was conducted in vitro, making it impossible to evaluate the effects of saliva, food, occlusal forces, repeated removal and insertion, or long-term wear. It has been demonstrated, for example, that alcohol plasticizes certain polymers, water causes filler leaching, and some microorganisms produce esterase enzymes that can degrade polymers.[7] Interestingly, however, it has been shown that occlusal impact does not contribute significantly to intraoral wear because of the rapid pre-impact deceleration of the mandible—although this neuromuscular reflex may not be as strong in individuals with bruxism.[8]

In our experience, buttons that have been light-cured to ACE retainers are extremely durable, remaining intact for the life of the ACE material, as long as two years. The ACE material itself provides excellent retention. We also find that buttons either cold-cured or light-cured to thermoplastic materials function better than slits for attachments, as discussed in a previous article.[2]

Conclusion

The specific choices of retainer material and acrylic resin are important in the fabrication of thermoplastic retainers with bonded attachments. In this study, the strongest combination of retainer and resin types was the DuraClear retainer and cold-cure acrylic, while the weakest combination was the DuraClear retainer and Triad VLP resin. Most of the bond strengths were sufficient, however, to permit in vivo orthodontic use. Further studies are needed to determine the clinical relevance of the study results.

REFERENCES

1. Sheridan, J.J.; McMinn, R.; and LeDoux, W.: Essix thermosealed appliances: Various orthodontic uses, J. Clin. Orthod. 29:108-113, 1995.
2. Rinchuse, D.J.; Rinchuse, D.J.; and Dinsmore, C.: Elastic traction with Essix-based anchorage, J. Clin. Orthod. 36:46-48, 2002.
3. Rinchuse, D.J. and Rinchuse, D.J.: Active tooth movement with Essix-based appliances, J. Clin. Orthod. 31:109-112, 1997.
4. Driscoll, C.F.; Woolsey, G.; and Ferguson, W.M.: Comparison of exothermic release during polymerization of four materials used to fabricate interim restorations, J. Prosth. Dent. 65:504-506, 1991.
5. Stipho, H.D. and Talic, Y.F.: Repair of denture base resins with visible light-polymerized reline material: Effect on tensile and shear bond strengths, J. Prosth. Dent. 86:143-148, 2001.
6. Dar-Odeh, N.S.; Harrison, A.; and Abu-Hammad, O.: An evaluation of self-cured and visible light-cured denture base materials when used as a denture base repair material, J. Oral Rehab. 24:755-760, 1997.
7. Söderholm, K.J. and Richards, N.D.: Wear resistance of composites: A solved problem? Gen. Dent. 46:256-263, 1998.
8. Bates, J.F.; Stafford, G.D.; and Harrison, A.: Masticatory function—a review of the literature, Part 2: Speed of movement of the mandible, rate of chewing and forces developed in chewing, J. Oral Rehab. 2:349-361, 1975.