Characteristics of light-polymerizable adhesives for bonding retentive beads to cut-back wax surfaces

Hiroyasu Koizumi, DDS, PhD,[a,b] Mamiko Kochi, DDS,[c] Kazuhiro Honda, DDS,[c] Michiya Ayano, DDS,[a] Kiyoshi Nagano, PhD,[d] and Hideo Matsumura, DDS, PhD[a,b]

[a]Department of Fixed Prosthodontics, [b]Division of Advanced Dental Treatment, Dental Research Center, Nihon University School of Dentistry, [c]Division of Applied Oral Sciences, Nihon University Graduate School of Dentistry, Tokyo, and [d]Nagasaki University Hospital, Nagasaki, Japan

Purpose: The purpose of the current study was to evaluate characteristics of chemical ingredients to be used for retentive beads adhesives.
Materials and Methods: An ultraviolet light-polymerizable adhesive (Particle Bond) and 12 UV and visible light-polymerizable compositions were assessed. Undercuts created on the surface of castings were evaluated using two retentive beads adhesives; Particle Bond and Retention Beads II Adhesive. The cross section of cast specimens was observed with a confocal scanning laser microscope.
Results: In addition to the composition of Particle Bond, a dual-polymerizable material consisting of 93.5% neopentylglycol diacrylate and 6.5% light initiators polymerized satisfactorily. In evaluation of the undercut of retentive devices, the ratio of diameter of bonded area and retentive bead at an identical cross section was 0.65 for Particle Bond and 0.49 for Retention Beads II Adhesive ($p<0.05$).
Conclusion: Although wetting ability and polymerization performance of the Particle Bond adhesive were excellent, there was room for improvement in reproduction of undercuts. A dual-polymerizable composition was proposed for the development of a new adhesive. **(Asian Pac J Dent 2011; 11: 15-18.)**
Key Words: adhesive, bead, cut-back, retentive device, spherical retention

Introduction

The application of highly loaded composite materials for veneering anterior and posterior restorations as well as pontics has increased substantially. This trend is attributed to the improvement in the properties of composite veneering materials. Mechanical retention, chemical retention, and a combination of both have been used for bonding between facing composites and framework alloys.

Among them, spherical retentive devices are widely accepted in dental laboratory procedures. Tanaka et al.[1] reported that bond strength between a heat-polymerized cross-linked resin and cast silver-palladium alloy was maximal when the diameter of retentive device was 0.18 mm. Lee et al.[2] used three materials for retaining a light-polymerized composite to cast nickel-chromium alloy with 0.35 mm retentive beads. The result was that cyanoacrylate adhesive exhibited greater retentive strength than a veneering resin and shellac. After the development of chemical bonding systems, retentive devices appeared to be eliminated in part.[3,4] However, laboratory and clinical experiences demonstrate that deterioration against physical or chemical attack of bonded veneers is smaller for mechano-chemically bonded systems than for mechanically or chemically bonded systems.

Although several papers reported data on retentive strength of mechanical bonding systems, only limited information is available about the characteristics of retentive beads adhesives.[5] This study evaluated polymerization performance of light-polymerizable retentive beads adhesives.

Materials and Methods

Polymerization characteristics

An ultraviolet (UV) light-polymerizable adhesive (Particle Bond; Toho Dental Products, Saitama, Japan) and 12 UV and visible light (VL) polymerizable compositions (UV-VL) were evaluated as retentive beads adhesives

(Table 1). Two laboratory light polymerization units were used for polymerizing the adhesives; a UV light polymerization unit (Twinkle Q, Toho Dental Products) and a xenon flash polymerization unit (Dentacolor XS; Heraeus Kulzer & Co., GmbH, Wehrheim, Germany). Thin layer of each adhesive was applied by brush to the surface of a piece of paraffin wax (GC Corp., Tokyo, Japan) and immediately light-exposed with one of the polymerization units for 10-30 s. The plate was manually bent after light exposure. More than four out of five specimens that showed crack propagation after light exposure were judged as polymerized group. The results of the UV-polymerizable composition were quoted from the previous work.[5]

Comparison of undercut of retentive beads

Undercuts created on the surface of castings were next evaluated. Rectangular specimens (5x5x2 mm) were fabricated with a wax material (Inlay Wax M; GC Corp.). One of the two retentive beads adhesives (Particle Bond; Toho Dental Products: Retention Beads II Adhesive; GC Corp.) was applied with a proprietary brush. Solvent of the Retention Beads II Adhesive was naturally evaporated. Retentive beads 200 μm in average diameter (Retention Beads II; GC Corp.) was next sprinkled on the adhesive layers. The Particle Bond adhesive was polymerized with the Twinkle Q unit for 20 s. The wax patterns with retentive beads were invested in a cristobalite mold material (Cristobalite Micro; GC Corp.) and Ag-Pd-Cu-Au alloy (Castwell M.C. 12; GC Corp.) was cast in the mold with a centrifugal casting apparatus. The castings were cut with a low-speed cutting saw with water coolant. The cut surfaces were observed with a confocal scanning laser microscope (1LM21W, Lasertec Corp., Yokohama, Japan) equipped with a He-Ne (Wavelength: 633 nm) laser light source. The diameter of bonded area divided by diameter of retentive bead within an identical cross section of the retentive bead was measured with a measuring system (LM eye, Lasertec Corp.). A diagram of the determination of the undercut is shown in Fig. 1.

Laboratory procedure

Fabrication of a typical framework of composite veneered restoration using the Particle Bond adhesive was planned. A technique for placement of retentive beads with proper undercut was proposed.

Table 1. Composition and polymerization characteristics of retentive beads adhesives

	Composition (wt%)				Polymerization unit and exposure time period (s)					
					Twinkle Q			Dentacolor XS		
	TMPTA	EHA	BME	DMABA	10	20	30	10	20	30
101	80	15	5		+	+	+	-	+	+
102	79.5	15	5	0.5	+	+	+	+	+	+
	NPGDA	BME	CQ	DMABA	10	20	30	10	20	30
201	97	3			-	-	-	-	-	-
202	95	5			-	-	-	-	-	-
203	96.5	3		0.5	-	-	-	-	-	-
204	94.5	5		0.5	-	-	+	-	-	+
205	98	1	1		-	-	-	-	-	-
206	96	3	1		-	-	-	-	-	-
207	94	5	1		-	-	-	-	-	-
208	97.5	1	1	0.5	-	+	+	-	+	+
209	95.5	3	1	0.5	-	+	+	-	+	+
210	93.5	5	1	0.5	+	+	+	+	+	+
211	99		1		-	-	-	-	-	-
212	98.5		1	0.5	-	-	+	-	+	+

TMPTA, trimethylol propane triacrylate; EHA, 2-ethylhexyl acrylate; BME, benzoin methyl ether; DMABA; *N,N*-dimethylamino-benzaldehyde; NPGDA, neopentylglycol diacrylate; CQ, *dl*-camphorquinone; (-), unpolymerized; (+), polymerized

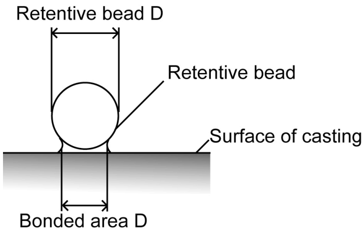
Results

Table 1 shows a comparison between polymerization characteristics of UV- and UV-VL-polymerized adhesive compositions. The composition 102 (Particle Bond) could be polymerized either with Twinkle Q or with Dentacolor XS after 10-s light exposure. Characteristics of The UV-VL-polymerizable compositions varied considerably. The results showed that incorporation of 6.5% of initiation system is necessary for the polymerization of UV-VL system based on neopentylglycol diacrylate (NPGDA).

Table 2. Comparison of undercuts generated with the use of two retentive beads adhesives

Retentive beads adhesive	Particle Bond (Composition #102)			GC Retention Beads II Adhesive		
	Median	IQR	Mean (SD)	Median	IQR	Mean (SD)
Bonded area D/Retentive bead D	0.65	0.17	0.63 (0.08)	0.49	0.08	0.49 (0.06)

D, diameter; Mean, n=20; Significant difference was found between the two systems (t-test, F=3.935, p<0.05).



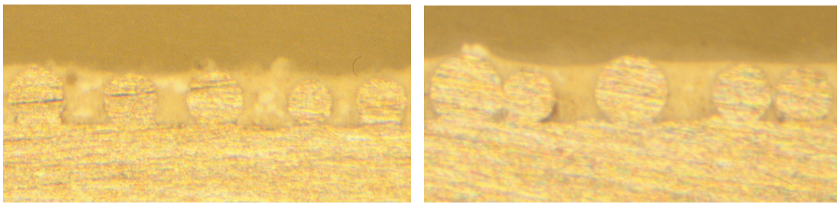


Fig. 1. Determination of undercut (left)
Fig. 2. Cross section of alloy castings prepared with Particle Bond (center) and Retention Beads II Adhesive (right)

Table 2 compares the undercuts generated with the use of two retentive beads adhesives. Ratio of diameter of bonded area and retentive bead at an identical cross section was 0.65 for the Particle Bond and 0.49 for the GC Adhesive. Figure 2 shows the cross sections of Ag-Pd-Au-Cu alloy castings. Difference in undercuts between the two systems can be observed.

Fig. 3. Cut-back wax pattern

Fig. 4. Application of Particle Bond

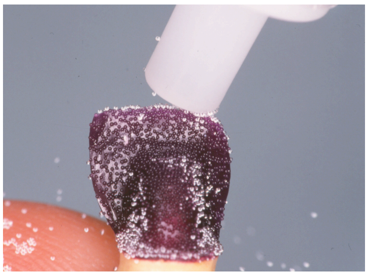


Fig. 5. Retentive beads (200 μm)

Fig. 6. Light-exposure for 20 s

Fig. 7. Polymerized adhesive

Fig. 8. Cast framework

Figures 3-8 show fabrication of Ag-Pd-Au-Cu alloy frameworks of resin veneered restorations using the Particle Bond adhesive. The reproduction of spherical retentive device appeared to be satisfactorily.

Discussion

This study evaluated the characteristics of light-polymerizable retentive beads adhesives. A UV light-polymerizable composition #102 was found to be effective in the previous study,[5] and the composition was released as the Particle Bond adhesive. The advantages of Particle Bond are; 1) low viscosity, 2) low thickness of oxygen inhibited layer, which is derived from a UV initiation system, and 3) adequate wetting ability to wax material. However, if the viscosity of the composition is too low, undercuts between retentive beads and wax surface are reduced by capillary phenomenon (Fig. 2 and Table 2). To alleviate this problem, application of a bi-functional aliphatic acrylate was proposed (Table 1). Also, considering the spread of intermediate visible-light sources designed for dental laboratories, a visible-light initiation system was adopted. It was found that composition #210 exhibited favorable polymerization performance. By application of more viscous composition, the capillary phenomenon, as observed in the Fig. 7, should be prevented.

The size of retentive beads, type of adhesive, mold material, casting alloy, casting technique, and alumina air-abrasion are key factors affecting mechanical retention between opaque resin materials and cast metal frameworks. Further investigation into these factors is necessary.

Acknowledgments

This work is supported in part by Grants-in-Aid for Scientific Research (C 20592283, C 21592474) from the Japan Society for the Promotion of Science (JSPS), Grant from Dental Research Center, and Sato Fund, Nihon University School of Dentistry (2009, 2010).

References

1. Tanaka T, Atsuta M, Uchiyama Y, Nakabayashi N, Masuhara E. Spherical powder for retaining thermosetting acrylic resin veneers. J Prosthet Dent 1978; 39: 295-303.
2. Lee CF, Pierpont HP, Strickler ER. The effect of bead attachment systems on casting patterns and resultant tensile bond strength of composite resin veneer cast restorations. J Prosthet Dent 1991; 66: 623-30.
3. Barzilay I, Myers ML, Cooper LB, Graser GN. Mechanical and chemical retention of laboratory cured composite to metal surfaces. J Prosthet Dent 1988; 59: 131-7.
4. Jones RM, Moore BK, Goodacre CJ, Munoz-Viveros CA. Microleakage and shear bond strength of resin and porcelain veneers bonded to cast alloys. J Prosthet Dent 1991; 65: 221-8.
5. Matsumura H, Tanaka T, Atsuta M. A light-cured acrylic adhesive for fixing resin retention devices to the wax pattern. J Jpn Prosthodont Soc 1990; 34: 364-71.

Correspondence to:

Dr. Hiroyasu Koizumi
Department of Fixed Prosthodontics, Nihon University School of Dentistry
1-8-13 Kanda-Surugadai, Chiyoda-ku, Tokyo 101-8310, Japan
Fax: +81-3-3219-8351 E-mail: koizumi@dent.nihon-u.ac.jp

Accepted December 27, 2010.

Copyright ©2011 by the *Asian Pacific Journal of Dentistry*. Online ISSN 2185-3487, Print ISSN 2185-3479