Shear Bond Strength of Denture Reline Polymers to Denture Base Polymers

Yutaka Takahashi, DDS, PhD[a]
John Chai, BDS, MS, MJ, DLaw[b]

Purpose: This study was undertaken to characterize the shear bond strength established between four denture base polymers and four denture reline polymers. **Materials and Methods:** Cylindric columns of denture reline polymers were bonded to columns of denture base polymers. Specimens were immersed in water for 4 months and then thermocycled. The strength at which the bond failed under shear stress was recorded. **Results:** Significant differences in bond strength existed among the specimens because of the denture base polymer variable, the denture reline polymer variable, and their interaction ($P < .05$). A light-activated denture base polymer (Triad) bonded adequately with a light-activated reline polymer (Triad) but less well with the other reline polymers tested. The bond strength established between some denture base polymers and a different light-activated reline polymer (Rebaron LC) was relatively low. **Conclusion:** The type of denture base polymer and denture reline polymer affected the shear bond strength between them. *Int J Prosthodont 2001;14:271–275.*

Chairside denture reline polymers serve to temporarily refit an acrylic resin denture base while the patient waits for the definitive prosthesis. Notwithstanding the transitional nature of its use, a denture reline polymer should possess adequate durability both esthetically and mechanically. The color stability of denture reline polymers depends on their chemical constituents and the amount of aging and weathering to which they are subjected.[1] The strength of a relined denture depends on the mechanical properties of the reline polymer and the denture base polymer individually.[2,3] It has also been suggested that the bond strength between the denture reline and denture base polymers might also affect the overall strength of the relined denture base.[4]

The more fundamental importance of adequate bond strength between the denture reline and denture base polymers is to ensure the retention of the reline polymer on the surface of the denture base to maintain the function of the reline polymer. A weakened bond between the polymers allows percolation of oral fluids, which can increase staining and bacteria harboring, whereas complete bond failure inevitably results in the delamination of the reline polymer.[5] The test of such bond strength has been performed most commonly with a transverse method.[5–7] A bar-shaped specimen of the denture base polymer is prepared. A certain length of the polymer bar is removed at its midpoint and replaced with a reline polymer. With the specimens supported close to its two ends, a compressive load is applied to the specimen at the midpoint of the length of the bar, where the reline polymer is situated. The failure load of the specimens with or without mathematic transformation is then presented as the "bond strength" between the denture reline and base polymers.

The validity of the transverse loading method of testing bond strength is questionable. Foremost, the nature of stress presented at one of the two denture reline–base polymer junctions is unknown. A bar-shaped specimen is subjected to predominantly bending stresses when loaded under such a three-point

[a]*Associate Professor, Department of Prosthodontics, Fukuoka Dental College, Fukuoka, Japan.*
[b]*Associate Dean, Academic Affairs, Northwestern University Dental School, Chicago.*

Reprint requests: *Dr John Chai, Northwestern University Dental School, 240 East Huron Street, Chicago, Illinois 60611. Fax: + (312) 503-0801. e-mail: jchai@nwu.edu*

Table 1 Denture Base and Reline Polymers Used

Material	Manufacturer	Processing method	Powder constituent(s)	Liquid constituent(s)	Batch No. (powder/liquid)
Denture base polymer					
Acron	GC	Compression-mold technique; heat processed at 70°C/90 min, then 100°C/30 min	PMMA	MMA (100%); EDMA trace	130481/030881
Acron MC	GC	Compression-mold technique; microwave processed at 500 W/3 min	PMMA	MMA; EDMA	100981/091181
Palapress Vario	Heraeus-Kulzer	Pour polymer system; 55°C at 2 kg/cm^2 pressure/15 min	PMMA	MMA (95.2%); 1,4-BuDMA (4.4%); TMBA (0.4%)	010438/010025
Triad	Dentsply	Light activation/10 min*	UDMA; silica fillers (14% w/w); PEMA	None	981002B
Denture reline polymer					
Rebaron	GC	No surface treatment; pour-mixed reline polymer	PMMA (with plasticizer	MMA	171171/141171
Tokuso Rebase	Tokuyama Soda	Rebase Aid bonding agent; pour-mixed reline polymer	PEMA	MAOP	980/868
Rebaron LC	GC	Rebaron LC bonding agent; pour-mixed reline polymer; 10 min light curing†	PEMA (with plasticizer	BMA (70%); UDMA (15%); TMPT (15%)	080982/270581
Triad	Dentsply	Visible light–cured bonding agent; 10 min light curing*	UDMA; silica fillers (14% w/w); PEMA	None	990115A

*Triad II (Dentsply).
†Labolite LV-1 (GC).
PMMA = poly(methyl methacrylate); MMA = methyl methacrylate; EDMA = ethylene glycol dimethacrylate (cross-linking agent); 1,4-BuDMA = 1,4-butanediol dimethacrylate (cross-linking agent); TMBA = trimethyl barbituric acid (accelerator); UDMA = urethanedimethacrylate; PEMA = poly(ethyl methacrylate); MOAP = β-methacryloyl oxyethyl propionate; BMA = isobutyl methacrylate; TMPT = trimethylolpropane trimethacrylate.

bending mode. The nature of the stress varies according to the location within the bar.[8] For example, the point of the bar immediately below the point of load application probably receives maximum compressive stress, whereas the midpoint on the opposite surface of the specimen bears the maximum tensile stress. The distribution of stress within the specimen is dependent on factors such as the dimensions of the specimen, the span distance between the supports, and the elastic modulus of the material.[8] As the elastic moduli of reline and base polymers vary according to the materials tested, the nature of stress presented at the reline–base polymer junction for different combinations of the specimens cannot be easily predicted or standardized. Thus, results of bond strength obtained from the transverse testing method must be interpreted with caution.

Tensile bond tests use, most frequently, bar- or rod-shaped specimens with denture reline and base polymers joined terminally.[1,9,10] Unlike the transverse bond test, the tensile method subjects the reline–base polymer junction to a simple tensile load, which allows the results to be easily compared between materials. The least frequently employed shear bond test applies a shear load directly to the reline–base polymer junction.[11] In addition to presenting a simple load at the junction, the shear mode of load could arguably represent better than tensile load what the reline–base polymer junction is subjected to clinically. The paucity of data on shear bond between denture reline and denture base polymers prompted the current study, the purpose of which was to characterize the shear bond strength between several denture reline and denture base polymers.

Materials and Methods

Four denture base polymers and four denture reline polymers were selected for the study. The denture base polymers were one conventional heat-processed, one microwave energy–processed, one pour-type autopolymerizing, and one light-activated denture base polymer. The reline polymers were two autopolymerizing and two light-activated denture reline polymers (Table 1).

Cylindric columns of each of the four denture base polymers were polymerized according to the manufacturers' instructions using a gypsum mold with a cavity of 10 mm in height and 8 mm in diameter (Table 1). For the purpose of mounting the specimen onto the load-testing machine (TCM-200, Minebea), each column of denture base was embedded in an acrylic resin tube with acrylic resin. The exposed end of the denture base surface was polished with 600-grit SiC paper (Carbimet, Buehler) and stored in 37°C distilled water for 1 day. Masking tape with a 6-mm-diameter hole was placed on the denture base surface, and a Teflon (DuPont) tube with a 5-mm internal

Table 2 Bond Strength (MPa) Between Denture Base and Reline Materials

Denture material	Reline material	Mean	Standard deviation	Significant groups*	No. of plain adhesive failures	No. of adhesive failures with crack in denture base	No. of cohesive failures
Acron	Rebaron	11.0	1.1	b,c,d	10		
Acron	Tokuso Rebase	11.7	2.0	b,c	7	3	
Acron	Rebaron LC	10.7	1.8	b,c,d	10		
Acron	Triad Reline	13.0	4.5	a,b,c	10		
Acron MC	Rebaron	9.5	1.5	c,d	10		
Acron MC	Tokuso Rebase	10.6	3.3	b,c,d	9	1	
Acron MC	Rebaron LC	7.5	2.1	d,e	10		
Acron MC	Triad Reline	10.6	5.5	b,c,d	9	1	
Palapress Vario	Rebaron	15.2	2.0	a	3	7	
Palapress Vario	Tokuso Rebase	11.1	1.4	b,c,d	6	4	
Palapress Vario	Rebaron LC	9.5	2.1	c,d	10		
Palapress Vario	Triad Reline	14.2	4.6	a,b	6	3	1
Triad	Rebaron	4.7	1.2	f	10		
Triad	Tokuso Rebase	9.4	1.8	c,d	10		
Triad	Rebaron LC	4.8	1.1	e,f	10		
Triad	Triad Reline	11.4	3.7	b,c,d	10		

*The same letter denotes groups that were not significantly different from each other ($P > .05$).

diameter and 5-mm height was positioned in the hole. Each of the four reline polymers were polymerized according to the manufacturers' instructions onto the denture base surface in the Teflon tube (Table 1). After the reline polymer was polymerized, the Teflon tubes and the tapes were removed. All specimens were stored in 37°C distilled water for 4 months. The 4-month water immersion protocol was adopted as a result of previous findings that the mechanical properties of denture polymers are affected by water immersion, and it can take as long as 4 months for the mechanical properties to attain equilibrium.[12,13] The specimens were then thermocycled between 4 and 60°C in 1-minute cycles for 10,000 cycles. This yielded ten specimens per group in each of the 16 denture base–reline material combinations. Compressive load was applied with a knife-edged blade placed parallel to the material interface on the load-testing machine at a cross-head speed of 1 mm/min. All tests were performed under uniform atmospheric conditions of 23.0 ± 1°C and 50% ± 1% relative humidity.

The data were analyzed statistically using two-way analysis of variance (ANOVA). The variables were denture base material and denture reline material. One-way ANOVA and the Newman-Keuls post hoc comparison were applied when appropriate (95% confidence level).

For all specimens, the interface where failure occurred was inspected. The failure was classified as either adhesive or cohesive in nature. An adhesive failure occurred if there was no trace of any denture base polymer on the denture reline polymer surface or vice versa. Alternatively, the presence of any trace of denture base polymer on the surface of the denture reline polymer or remnants of the denture reline polymer on the denture base indicated a cohesive failure.

Results

Two-way ANOVA revealed that there were significant differences in bond strength because of the denture reline polymer variable, the denture base polymer variable, and their interaction ($P < .05$). One-way ANOVA and the Newman-Keuls post hoc comparison were applied to the denture reline–base polymer combination. The results are depicted in Table 2.

The mean bond strengths between the denture reline–base polymers varied from the lowest value between Triad base and Rebaron reline polymers (4.7 MPa) to the highest value between Palapress Vario base and Rebaron reline polymers (15.2 MPa). Among the denture base polymers in general, the pour-type polymer, Palapress Vario, and heat-processed polymer, Acron, possessed better bond strength to denture reline polymers than the microwave energy–processed polymer, Acron MC, and the light-activated polymer, Triad. The bond strengths of the Triad base–Rebaron LC reline polymer and Triad base–Rebaron reline polymer combinations were significantly lower than most of the other polymer combinations.

In contrast to the Triad denture base polymer, the Triad reline polymers appeared to bond well to the denture base polymers. The bond strengths between Tokuso Rebase and each of the four denture base polymers were not significantly different from those between Triad reline polymer and the four denture base polymers. The bond strength of Rebaron reline polymer seemed to be more dependent on the denture base polymer than either the Tokuso Rebase or Triad reline polymers. For example, Rebaron showed both the highest (Palapress Vario base–Rebaron reline polymer) and the lowest (Triad base–Rebaron reline polymer) bond strengths to denture base polymers. In comparison to other denture reline polymers, Rebaron LC generally possessed lower, if not the lowest, bond strength to any of the four denture base polymers.

Upon examining the mode of failure of the specimens, the adhesive mode of failure was further subdivided into two submodes: plain adhesive failure in which no visible trace of material adhered on its counterpart, and adhesive failure with a visible crack in the denture base material (Table 2). It appeared generally that the specimens that failed with a crack in the denture base material possessed higher bond strength than those that failed plainly adhesively. Only one sample failed cohesively, with remnants of the Palapress Vario denture base polymer adhered to the Triad reline polymer.

Discussion

Successful bonding between the denture reline and base polymers relies on the effective penetration of monomers emanating from the polymerizing denture reline polymer into the denture base.[11,13] An adequate amount of monomer has to be available to interact with the denture polymer to form an interpenetrating polymer network to secure a bond.[13] It had been proposed that highly cross-linked denture or denture teeth polymers restrict the penetration of monomers because of the high density of the polymer network, and thus are not as effectively bonded to as their less cross-linked counterparts.[13,14] The present study showed that the bond strengths between the reline polymers and Triad denture base polymer were generally lower than those with other denture base polymers. This may be attributed to the highly cross-linked nature of the Triad denture base polymer because of its composition of urethanedimethacrylate and acrylic copolymer.[13,15]

In studies previously undertaken by the current authors on the strength of relined denture specimens, Triad denture base relined with various reline polymers displayed flexural strength lower than expected based on the high flexural strength of bulk Triad denture base polymer.[12,13] The reason proffered for such an observation was the possibility of diminished bond strength between Triad denture base polymer and reline polymers in comparison with the bond strength achieved with other denture base polymers.[13] This hypothesis was at least partially proven with the current results.

The trend that Triad denture base bonded less effectively than other denture base materials was not observed in an earlier investigation that reported the transverse bond strength of various reline polymers to denture polymers.[5] The difference in the method of testing bond strength probably explains the different results. As in the present study, it was shown that Triad reline polymer bonded better to Triad denture base than did other reline polymers. Chemical similarity between the Triad reline and Triad denture polymers was cited to explain the observation.[5]

Confirming the results of other studies,[5,10] the present study proved that Triad reline polymer also bonded well to other denture polymers in addition to Triad denture polymer. The bond strengths established between Triad reline polymer and various denture base polymers were comparable to those established with Tokuso Rebase reline polymer, an autopolymerizing polymer. This finding is in agreement with a previous study that found no significant difference in transverse bonding strength achieved by Triad reline polymer and an autopolymerizing polymer,[6] but contradicts another study that showed the shear bond strength of Triad reline polymer to be inferior to that of an autopolymerizing polymer.[11] As mentioned earlier, the amount of monomer available from the polymerizing denture reline polymer at the bonding surface could affect the strength of the bond. It is likely that variation in monomer availability from the different autopolymerizing polymers accounted for the diverse results.

The relatively low bond strength established by Rebaron LC, the other light-activated reline polymer tested in the study, is a matter of concern. Further experimentation is necessary to explain this observation.

Under the conditions of the present experiment, it can be concluded that the type of denture base polymer and denture reline polymer affected the bond strength between them. Most bonds established between the materials tested appeared to be adequate. Triad denture base polymer bonded well with Triad denture reline polymer, but not as well to the other denture reline materials tested. The bond strengths established between a light-activated reline material, Rebaron LC, and some denture base polymers were low in comparison.

References

1. Bunch J, Johnson GH, Brudvik JS. Evaluation of hard direct reline resins. J Prosthet Dent 1987;57:512–519.
2. Takahashi Y, Kawaguchi M, Chai J. Flexural strength at proportional limit of a denture base material relined with four different denture reline materials. Int J Prosthodont 1997;10:508–512.

3. Chai J, Takahashi Y, Kawaguchi M. The flexural strengths of denture base acrylic resins after relining with a visible-light activated material. Int J Prosthodont 1998;11:121–124.
4. Takahashi Y, Chai J, Kawaguchi M. The strength of relined denture base polymers subjected to long-term water immersion. Int J Prosthodont 2000;13:205–208.
5. Arena CA, Evans DB, Hilton TJ. A comparison of bond strengths among chairside hard reline materials. J Prosthet Dent 1993;70:126–131.
6. Lewinstein I, Zeltser C, Mayer CM, Tal Y. Transverse bond strength of repaired acrylic resin strips and temperature rise of dentures relined with VLC reline resin. J Prosthet Dent 1995;74:392–399.
7. Machado Cucci AL, Bergani CE, Giampaolo ET, da Silveira Ferreira Afonso MC. Water sorption solubility and bond strength of two autopolymerizing acrylic resins and one heat-polymerizing acrylic resin. J Prosthet Dent 1998;80:434–438.
8. Jayatilaka AS. Fracture of Engineering Brittle Materials. London: Applied Science 1979:181–188.
9. Razavi R, Khan Z, von Fraunhofer JA. The bond strength of a visible light-cured reline resin to acrylic resin denture base material. J Prosthet Dent 1990;63:485–487.
10. Smith FT, Powers JM. In vitro properties of light-polymerized reline materials. Int J Prosthodont 1991;4:445–448.
11. Curtis DA, Eggleston TL, Marshall SJ, Watanabe LG. Shear bond strength of visible-light-cured resin relative to heat-cured resin. Dent Mater 1989;5:314–318.
12. Takahashi Y, Chai J, Kawaguchi M. Equilibrium strengths of denture polymers subjected to long-term water immersion. Int J Prosthodont 1999;12:348–352.
13. Takahashi Y, Chai J, Kawaguchi M. Strength of relined denture base polymers subjected to long-term water immersion. Int J Prosthodont 2000;13:205–208.
14. Takahashi Y, Chai J, Takahashi T, Habu T. Bond strength of denture teeth to denture base resins. Int J Prosthodont 2000;13:59–65.
15. Al-Mulla MAS, Huggett R, Brooks SC, Murphy WM. Some physical and mechanical properties of a visible light-activated material. Dent Mater 1988;4:197–200.

Literature Abstract

Obtaining measurable bilateral simultaneous occlusal contacts with computer-analyzed and guided occlusal adjustments.

This report describes a clinical technique that uses computerized occlusal analysis of occlusal contact time and force information to guide the occlusal adjustment of a mandibular closure to obtain true and measurable bilateral occlusal contact simultaneity. The system used, T Scan II, is a Microsoft Windows–compliant system that has been integrated into a clinical, diagnostic computer workstation. An IBM-compatible computer, a Pentium processor, and a minimum of 4 to 8 megabytes of RAM are required to properly operate the system. The graphic interface uses familiar Windows toolbar icons to display the software features that are used to analyze occlusal contact information. Numerous authors and textbooks have advocated the concept of bilateral simultaneous occlusal contacts as one of the necessary components of an optimum occlusal condition. All occluding surfaces should meet at the same time during a mandibular closure. Computerized occlusal analysis shows that widely used paper labeling does not accurately represent true bilateral occlusal contact simultaneity. Articulating paper labeling is an inadequate indicator of perceived occlusal contact simultaneity, as it renders no occlusal contact force or time sequencing. When occlusal adjustments are guided by computerized occlusal analysis, occlusal contacts on all potentially occluding teeth can be approximated to occur within 0.2 second. It was concluded that by employing computerized occlusal analysis of a mandibular closure to guide the occlusal adjustments of the contact sequence, the establishment of true and measurable bilateral simultaneous occlusal contacts can now be an attainable clinical reality. This conclusion was not supported by any controlled study but by "clinical anecdotal observation by [the] author over the past 15 years."

Kerstien RB, Grundset K. *Quintessence Int* 2001;32:7–18. **References:** 21. **Reprints:** Dr Robert B. Kerstein, 665 Beacon Street, #204, Boston, Massachusetts 02215. e-mail: Tmjdoc@IX.Netcom.com—*AW*