The Effect of Water Immersion on the Shear Bond Strength Between Chairside Reline and Denture Base Acrylic Resins

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Purpose: The effect of water immersion on the shear bond strength (SBS) between 1 heat-polymerizing acrylic resin (Lucitone 550-L) and 4 autopolymerizing reline resins (Kooliner-K, New Truliner-N, Tokuso Rebase Fast-T, Ufi Gel Hard-U) was investigated. Specimens relined with resin L were also evaluated.

Materials and Methods: One hundred sixty cylinders (20 × 20 mm) of L denture base resin were processed, and the reline resins were packed on the prepared bonding surfaces using a split-mold (3.5 × 5.0 mm). Shear tests (0.5 mm/min) were performed on the specimens (n = 8) after polymerization (control), and after immersion in water at 37°C for 7, 90, and 180 days. All fractured surfaces were examined by scanning electron microscopy (SEM) to calculate the percentage of cohesive fracture (PCF). Shear data were analyzed with 2-way ANOVA and Tukey's test; Kruskall-Wallis test was used to analyze PCF data ($\alpha = 0.05$).

Results: After 90 days water immersion, an increase in the mean SBS was observed for U (11.13 to 16.53 MPa; $p < 0.001$) and T (9.08 to 13.24 MPa, $p = 0.035$), whereas resin L showed a decrease (21.74 MPa to 14.96 MPa; $p < 0.001$). The SBS of resins K (8.44 MPa) and N (7.98 MPa) remained unaffected. The mean PCF was lower than 32.6% for K, N, and T, and higher than 65.6% for U and L.

Conclusions: Long-term water immersion did not adversely affect the bond of materials K, N, T, and U and decreased the values of resin L. Materials L and U failed cohesively, and K, N, and T failed adhesively.

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INDEX WORDS: acrylic resins, relining, water storage, shear strength

DIRECT RELINING of denture bases in the mouth with autopolymerizing acrylic resins is not only faster than laboratory-processed reline systems, but also can reproduce the morphologic features of oral soft tissue directly on the denture base.[1] Among other factors, adequate bond strength between the autopolymerizing reline acrylic resin and the denture base acrylic resin is essential for successful relining of ill-fitting denture bases and should be considered when selecting the reline material. A weak bond probably will result in adhesive failures at the interface between the reline resin and the denture base material under relatively low stresses.[2] These bond failure sites could harbor bacteria, promote staining, or result in delamination of the two materials.[1,3-5]

The bonding between the denture base and reline resins is due to the diffusion, penetration, and polymerization of the reline monomers across the reline-denture base interface to form interpenetrating polymer networks.[6] Current hard denture relining materials contain a variety of methacrylate monomers instead of methyl methacrylate.[7] When compared with conventional polymers based on methyl methacrylate, the bond strength of these highly cross-linked reline

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resins could not be effective due to low penetration of the monomers with relatively greater molecular weight.[4,8] Although surface treatments such as roughening or the application of surface primers before relining have been recommended by the manufacturers to improve bonding, adhesive mode of failure has been systematically reported.[5,6,9–12] In addition, severe loss of reline material from the borders and impression surfaces of lower complete dentures has been observed after 12 months of placement.[1] Therefore, where direct relining is concerned, bonding failure still remains a critical factor and needs to be further investigated.

During clinical use the acrylic resins are either immersed in saliva or soaked in denture cleansing solutions or water. The absorbed water molecules, which act as a plasticizer,[13,14] may percolate directly at the bond interface and, according to the results of Aydin et al[15] and Cucci et al,[16] decrease the bond strength between the denture base and the reline resin. Therefore, the effect of water immersion is another clinically relevant factor that may influence the durability of the bond between the denture base and reline materials.

Considering that the effect of water on the bond strength of reline resins has mostly been investigated using short periods of immersion,[10,16–18] and that new reline resins are constantly being introduced, the aim of this study was to evaluate the effect of long-term water immersion on the shear bond strength between one heat polymerizing denture base acrylic resin and four autopolymerizing hard chairside reline acrylic resins. The bond strength of the denture base acrylic resin relined with the same material was also evaluated for comparison. The hypothesis tested was that long-term water immersion would adversely affect the shear bond strength of denture base/reline material.

Materials and Methods

The product names, batch numbers, manufacturers, compositions, powder/liquid proportions, and polymerization cycles of the materials used in the present study are listed in Table 1.

In preparing the specimens, PVC tubes (Tigre S/A, Tubos e Conexões, Joinville, SC, Brazil) were used for fabrication of 20 × 10 mm wax (Wilson, Polidental Indústria e Comércio Ltda, São Paulo, SP, Brazil) cylinders, which were then invested in flasks (OGP

Table 1. Materials Used

Material	*Batch No.*	*Manufacturer*	*Powder Composition*	*Liquid*		*Powder/Liquid Ratio (g/ml)*	*Polymerization Cycles*
				Composition	*Molecular*		
Kooliner	0201102	GC America Inc, Alsip, IL	PEMA	IBMA	142	2.1 g/1.0 ml	10 minutes at room temperature
New Truliner	0310-528	The Bosworth Co., Skokie, IL	PEMA	IBMA DBP	142 278	1.34 g/1.0 ml	20 minutes at room temperature
Tokuso Rebase Fast	U570612	Tokuyama Dental Corp., Tokyo, Japan	PEMA	MAOP 1,6-HDMA	186 254	2.056 g/1.0 ml	5.5 minutes at room temperature
Ufi Gel Hard	025292	Voco, Cuxhaven, Germany	PEMA	1,6-HDMA	254	1.76 g/1.0 ml	7 minutes at room temperature
Lucitone 550	P-65173 L-37375	Dentsply Indústria e Comércio Ltda., Petrópolis, RJ, Brazil	PMMA	MMA EDGMA	100 198	2.1 g/1.0 ml	90 minutes at 73°C and 30 minutes at 100°C

PEMA = poly (ethyl methacrylate); PMMA = poly(methyl methacrylate); IBMA = isobutyl methacrylate; DBP = di-*n*-butyl phthalate; MAOP = β-methacryloyl oxyethyl propionate; 1,6-HDMA = 1,6-hexanediol dimethacrylate; MMA = methyl methacrylate; EDGMA = ethylene glycol dimethacrylate.

3.0, OGP Produtos Odontológicos, São Paulo, Brazil) using Type IV dental stone (Troquel Quatro, Polidental Indústria e Comércio Ltda). After elimination of the wax, the denture base resin Lucitone 550 was mixed and packed into the PVC tubes using a hydraulic press (Vipi Dental, Pirassununga, São Paulo, SP, Brazil). A total of 160 denture base resin cylinders, 32 for each denture base/reline material combination, were polymerized in a water bath (P-100, Termotron equipamentos, Piracicaba, SP, Brazil) using the short cycle recommended by the manufacturer (Table 1). After polymerization, the processed flask was left to cool at room temperature for 30 minutes and then was placed under running water for 15 minutes. The specimens were removed from the flasks and stored in distilled water at 37 ± 1°C for 50 ± 2 hours.[19] After water storage, the denture base resin surfaces to be bonded were smoothed on 240 grit silicone carbide paper (3M do Brazil, Ribeirão Preto, SP, Brazil), in an automatic grinding and polishing unit (Metaserv 2000, model 95-2829, Buehler UK Ltd., Coventry, England) at 350 rpm for 40 seconds, to simulate clinical relief of the denture base for bonding of the reline resins. The 240 grit paper has been used for surface preparation in investigations on the bond strength between hard chairside reline and denture base acrylic resins.[12,15,20] The surfaces were then brushed with liquid detergent (Limpol, Bombril-Cirio, São Paulo, SP, Brazil) for 20 seconds, washed in distilled water, and blot-dried. Thereafter, surfaces were treated according to the manufacturer's instructions for each hard chairside reline material, with the exception of Kooliner resin, for which the bonding sites were prepared by painting the surfaces with Lucitone monomer for 180 seconds. This procedure was based on the results of a previous study,[11] which demonstrated that wetting the denture base resin surface with Lucitone 550 monomer improved the sites for bonding and promoted the highest flexural bond strength for Kooliner. Masking tape with a 3.5 mm diameter circular opening was placed on the treated denture base surfaces to provide a uniform bonding area (9.62 mm^2).

A specially designed metal split mold having a circular opening (3.5 mm diameter × 5.0 mm length) was used for the relining procedures. The denture base cylinder was placed in the mold and secured via screws, so the metal mold opening position coincided with the masking tape opening position. The autopolymerizing reline materials were then mixed according to the manufacturers' instructions, and inserted into the 3.5 × 5.0 mm split mold opening. An acetate sheet was placed over the material, and pressure was applied until polymerization was completed. The screws were loosened, the two parts of the mold were separated, and the relined specimen was removed.

When the specimens were relined using the heat-polymerizing acrylic resin Lucitone 550, initially the denture base cylinders were invested in Type IV dental stone to half their length within the first part of the flask. A metal die (3.5 mm diameter and 5.0 mm length) was directly glued to the center of the bonding surface with a small drop of cyanoacrylate glue (Super Bonder, Henkel Loctite Products, Rocky Hill, CT). Low viscosity silicone rubber impression material (Oranwash L, Zhermack, Badia Polesine, Rovigo, Italy) was injected onto the die, and high viscosity silicone impression material (Zetaplus, Zhermack, Badia Polesine) was then applied. The second part of the flask was positioned and filled with Type IV dental stone, which was allowed to set. The flask was opened, the metal die was removed, and the bond surface was prepared as described and treated with Lucitone 550 monomer for 180 seconds.[21] The masking tape was positioned on the bonding surface, and the denture base acrylic resin Lucitone 550 was mixed, inserted into the silicone mold, and polymerized under pressure (Table 1). After polymerization, the flask was cooled to room temperature and the specimens were deflasked and stored in distilled water at 37 ± 1°C for 50 ± 2 hours.[19]

The 32 specimens of each reline material were divided into 4 groups (n = 8). The control specimens of the hard chairside reline resins (C) were submitted to the shear tests within 30 minutes of polymerization, whereas the denture base material Lucitone 550 control specimens were tested after being immersed in water at 37 ± 1°C for 50 ± 2 hours.[19] For the other experimental groups, specimens were tested after being immersed in water at 37 ± 1°C for 7 days (Wim7d), 90 days (Wim90d), and 180 days (Wim180d).

For shear bond tests, each specimen was mounted in a metal holder on the universal testing machine (MTS-810, Material Test System, Eden Prairie, MN) and loaded with a knife-edged blade positioned parallel to the material interface at a 0.5 mm/min crosshead speed.[22] The tests were conducted in air at room temperature (23 ± 2°C), and the shear bond strengths (MPa) were calculated by dividing the force required to break the specimen by surface area of adhesion (9.62 mm^2).

After shear tests, all fractured surfaces were sputter coated with gold and observed via scanning electron microscopy (SEM) (Stereoscan 440, Leica, Cambridge, UK) at original magnification × 50. The SEM micrographs were then examined using an image analyzer (Leica) to determine the mode of debonding. This was done by tracing the borders of the cohesive reline/denture base fracture that remained within the debonded interface and calculating the area using the QWin program (Leica). The percentage of cohesive fracture within the reline material was calculated by dividing this area by the total bonded area. All images were analyzed by one investigator, masked to specific experimental conditions. Twenty images from different specimens were used to calibrate the examiner. The area of the cohesive reline/denture base fracture was measured, and two hours later the same examiner read the 20 images again to evaluate the intra-examiner reproducibility. Calibration was accepted if the t-test applied to the data showed no significant difference between the two sets of readings.

Data from shear tests were analyzed using 2-way analysis of variance (ANOVA) followed by Tukey Honestly Significant Difference (HSD) *post hoc* test. Since data from the percentage of cohesive fracture had an inhomogeneous distribution, the results were submitted to the nonparametric Kruskal–Wallis test, followed by multiple comparisons to determine whether there were significant differences among materials and groups. Significance level was set at $p = 0.05$.

Results

Table 2 presents the mean shear bond values and the standard deviations for all experimental conditions evaluated. Ufi Gel Hard specimens immersed in water for 90 days (Wim90d) exhibited significantly higher ($p < 0.001$) mean values than those immersed in water for 7 days (Wim7d). For Tokuso Rebase Fast, Wim90d specimens showed significantly higher mean bond strength values than control group specimens ($p = 0.035$). From 7 days to 90 days of water immersion, Lucitone 550 specimens showed a significant reduction in mean shear bond strength ($p < 0.001$). No significant difference was found between groups Wim90d and Wim180d, which in turn was significantly lower than the control group ($p < 0.001$). For materials Kooliner and New Truliner, no significant differences were found among all groups evaluated.

When control group specimens were compared, the mean shear bond strength value was highest with Lucitone 550 denture base acrylic resin ($p < 0.001$). Ufi Gel Hard was statistically different from Kooliner ($p = 0.006$), Tokuso Rebase ($p = 0.050$), and New Truliner ($p = 0.001$) and had the highest shear bond strength among the hard chairside reline resins. There were no significant differences in shear bond strengths among Kooliner, Tokuso Rebase Fast, and New Truliner materials. After 180 days of water immersion, no significant differences were found between Lucitone 550 acrylic resin and Ufi Gel Hard, Tokuso Rebase Fast, and Kooliner. New Truliner exhibited significantly lower mean shear bond strength values than Lucitone 550 acrylic resin ($p = 0.018$).

Examination of the fracture sites revealed that Kooliner specimens immersed in water showed a significantly ($p < 0.05$) lower percentage of cohesive fracture within the reline material than control group specimens, regardless of immersion time period (Table 3). Lucitone 550 specimens immersed in water for 90 days exhibited significantly less reline material left on the denture base surface compared with the other immersion groups evaluated ($p < 0.05$). For Tokuso Rebase Fast, New Truliner, and Ufi Gel Hard no significant differences were detected among the groups evaluated (Table 3).

Comparisons among materials revealed that Kooliner, Tokuso Rebase Fast, and New Truliner showed failure primarily at the interface, with 32.6% or less residue of reline material remaining on the denture base surface. In contrast, for Lucitone 550 and Ufi Gel Hard the percentage area of remnants of the reline resin on the denture base surface ranged from 65.6% to 100% and 71.7% to 100%, respectively.

Discussion

The shear bond test used in the present investigation applies a shear load directly to the

Table 2. Shear Bond Strength Mean Values (MPa) and Standard Deviations of Acrylic Resins and Groups Evaluated

	Groups			
Materials	*C*	*Wim7d*	*Wim90d*	*Wim180d*
Lucitone 550	18.89 ± 2.06^{ab}A	21.74 ± 2.76^{a}A	14.96 ± 3.16^{bc}A	12.33 ± 2.84^{c}A
Ufi Gel Hard	13.12 ± 2.22^{ab}B	11.13 ± 1.60^{b}B	16.53 ± 1.64^{a}A	12.79 ± 2.09^{ab}A
Tokuso Rebase Fast	9.08 ± 2.45^{b}C	12.40 ± 2.02^{ab}B	13.24 ± 2.58^{a}A	9.47 ± 2.14^{ab}AB
Kooliner	8.44 ± 2.46^{a}C	8.42 ± 2.75^{a}B	9.01 ± 2.15^{a}B	9.83 ± 2.39^{a}AB
New Truliner	7.98 ± 1.94^{a}C	9.53 ± 1.83^{a}B	6.68 ± 1.92^{a}B	7.95 ± 1.88^{a}B

Note: Horizontally, identical superscripted small letters denote no significant differences among groups ($p > 0.05$). Vertically, identical capital letters denote no significant differences among materials ($p > 0.05$).

Table 3. Percentage Mean Values of Cohesive Fracture within the Reline Material

	Groups			
Materials	C	Wim7d	Wim90d	Wim180d
Lucitone 550	100.0^{a}B	100.0^{a}B	65.6^{b}B	100.0^{a}B
Ufi Gel Hard	86.7^{a}B	71.7^{a}B	77.3^{a}B	100.0^{a}B
Tokuso Rebase Fast	29.9^{a}A	2.0^{a}A	18.1^{a}A	16.9^{a}A
Kooliner	32.6^{a}A	1.0^{b}A	8.7^{b}A	0.5^{b}A
New Truliner	23.1^{a}A	5.5^{a}A	2.8^{a}A	6.9^{a}A

Note: Horizontally, identical superscripted small letters denote no significant differences among groups ($p > 0.05$). Vertically, identical capital letters denote no significant differences among materials ($p > 0.05$).

reline-denture base polymer junction and represents better than tensile load what the reline-denture base polymer interface is subjected to clinically.[6] In addition, this test has been used by several investigators to determine the bond strengths of denture base acrylic resins to reline materials[6,8,12,20] and denture teeth.[23,24] The results demonstrated that Ufi Gel Hard exhibited an increase in the mean bond strength from 7 days to 90 days water immersion. Similar results were found for Tokuso Rebase Fast, which showed significantly higher mean bond strength after 90 days of water immersion compared with control. In addition, no significant changes were observed in the bond strength of the autopolymerizing reline materials Kooliner and New Truliner after water immersion. These findings were not expected, because the absorbed water molecules[7,10,25] may act as plasticizers within the polymer network and lead to a decrease in both the mechanical strength of the polymerized reline materials[13,14] and their bond to the denture base.[15,16] Taking into account that the addition of cross-linking agents in the liquids of reline acrylic resins decreases their water sorption,[7,26] it could be supposed that the absence of adverse effect of water immersion on the bond strength results of Ufi Gel Hard and Tokuso Rebase Fast could be related to the high percentage of the cross-linking agent 1, 6-hexanediol dimethacrylate in these materials. The increase in bond strength with time observed for these materials may be attributed to a continuous polymerization reaction where residual monomer molecules are progressively consumed,[27] thus reducing their plasticizing effect. In addition, the content of the residual monomer molecules could have been reduced by release into the water[28,29] during the 90-day water immersion period and could have accounted for the increase in the bond strength mean values of Ufi Gel Hard and Tokuso Rebase Fast reline resins. Takahashi et al[14] also found a significant increase in the flexural strength of Tokuso Rebase from 1 day to 3 months of water immersion. Despite the changes in mean bond strength, the analysis of the fractured surfaces of Ufi Gel Hard and Tokuso Rebase Fast failed to find significant differences in the percentage of cohesive fracture for both materials.

Although Kooliner and New Truliner may also have undergone continuous polymerization and leaching of residual monomer during water immersion, an increase in bond strength was not observed. Since these materials do not contain cross-linking agents, it could be that the plasticizing effect of the water molecules absorbed during the storage period counteracted any improvement in bond strength resulting from further polymerization and monomer release. The analysis of the interface where failures occurred revealed that immersion in water resulted in a significant reduction of the percentage mean values of cohesive fracture within the Kooliner reline material compared with control. Aydin et al[15] investigated the bond strength between reline resins and one heat-polymerized denture base acrylic resin and examined the adhered surfaces by SEM. They observed that Kooliner initially demonstrated very good adhesion, but separation of a few microns thick formed over the 90 days of water immersion. Previous studies also have found that Kooliner reline resin generally failed adhesively with the denture base materials.[5,9,10,12,16]

Different from the autopolymerizing reline resins, the denture base acrylic resin Lucitone 550 showed a significant decrease in the mean bond strength value from 7 days to 90 days of water immersion. In addition, after 180 days of immersion, the specimens exhibited significantly lower mean values than those of control specimens. Accordingly, microscopic examination of the fracture sites revealed that the percentage of cohesive fracture within the reline material at 90 days of immersion was significantly lower than the other groups evaluated. This finding suggests that the water affected to some extent the denture base/reline resin interface. Nevertheless, the failures were mainly cohesive with 65.6% area of remnants of the reline resin on the denture base surface. In addition, for the 180-day immersion period, all specimens failed cohesively. A cohesive failure, where fracture occurs within the reline material, provides information on the strength of the reline material itself. Therefore, the results from the shear tests, together with the type of failures, indicate that, in addition to the interface, the strength of Lucitone 550 was also adversely affected by water immersion. The studies from Takahashi et al[13,14] investigated the flexural strength of denture base acrylic resins after storage in water at 37°C for periods of 1 day up to 4 months. Their results demonstrated that the heat-polymerizing denture base acrylic resins exhibited a significant decrease in the flexural strength, which was attributed to the water plasticizing effect. Therefore, it is likely that the lower mean value for the 180-days-immersed Lucitone 550 specimens compared with control specimens could be related to the plasticizing effect of the water molecules absorbed within this material.

When control group specimens were compared, Lucitone 550 exhibited the highest mean shear bond strength, with all specimens showing cohesive failure. Several factors may have contributed to these findings, among them the higher polymerization temperature of Lucitone 550 specimens compared with the autopolymerizing reline resins specimens. It has been shown that the higher the polymerization temperature, the higher the diffusion rates of the monomers with increasing bond strength between the polymers.[23,30] The diffusion of monomers also increases with the increase in time before polymerization commences.[23,30] Because Lucitone 550 remained in the doughy state until the heat was applied, more time was available for the diffusion of the monomer into the polymerized denture base acrylic resin, thus favoring the achievement of an increased bond.[23,30] Another possible explanation for the highest mean shear bond strength of Lucitone 550 control specimens could be the chemical similarity between the two polymers,[5,6] as in these specimens the denture base and the reline resin were the same material. The smaller size of methyl methacrylate molecules compared with the monomers contained in the autopolymerizing resins may have facilitated its penetration into the denture base polymer, thus resulting in the highest mean bond strength for Lucitone 550 control specimens. However, it should be noted that after 180 days of water immersion, New Truliner was the only autopolymerizing reline resin that produced significantly lower mean bond strength than that of the specimens relined using the heat-polymerizing denture base acrylic resin. The favorable bond strengths of Kooliner, Ufi Gel Hard, and Tokuso Rebase Fast, together with the fact that these autopolymerizing reline resins give a considerable saving on clinical time, suggest that they are reliable for denture base relining.

The results from control specimens also demonstrated that Ufi Gel Hard showed the highest mean bond strength among the autopolymerizing reline resins evaluated. Moreover, the area of Ufi Gel Hard left on denture base bond surface was significantly higher than those of the other autopolymerizing reline resins. The bonding agent supplied by Ufi Gel Hard's manufacturer contains the solvent dichloromethane, which is a nonpolymerizable solvent[12] that may dissolve the surface of the denture base and promote penetration of the reline acrylic resin into the denture base resin, resulting in the formation of a mixed layer of reline acrylic resin and denture base resin.[4] In addition, it has been observed that acrylic surfaces treated with dichloromethane revealed pores and channels, which probably represent spaces previously occupied by resin polymer that had been dissolved.[31] These features suggest micromechanical retention as another mechanism to explain the effect of dichloromethane in improving bonding.[31] Although Tokuso Rebase Fast bonding agent contains an organic solvent (methylene chloride), its mean bond strength was significantly lower than that of Ufi Gel Hard. This may be due to the fact that Ufi Gel Hard bonding agent also contains the monomer 2-hydroxy ethyl methacrylate, which may penetrate into the dissolved denture base surface and polymerize along with the reline resin.[4] Bonding agents containing both solvents and monomers have been reported to have a positive effect on the bond strength of denture base to reline resins[12] and denture teeth.[32] The mean shear bond strengths of Kooliner and New Truliner control specimens were also significantly lower than those of Ufi Gel Hard specimens. The bonding agent of New Truliner contains methyl methacrylate,[4] which is also contained in the liquid of Lucitone 550 used for wetting the bonding surface when Kooliner reline resin was used. It has been reported that methyl methacrylate monomer has a relatively low ability to dissolve the denture base resin surface.[4]

Other studies have investigated the bond strength between reline and denture base acrylic resins[5,6,8-12,15-18,20]; however, due to differences in methodology, only indirect comparisons between results can be made. In the present investigation the specimens were not submitted to thermal cycling as suggested by Minami et al,[8] who observed a significant reduction in shear bond strength of thermal cycled specimens. Despite this limitation, the shear bond strength results from the present investigation were similar to those reported by Takahashi and Chai,[6] who also submitted the specimens to thermal cycling before the shear tests. Therefore, other differences in methodology in addition to thermal changes may have contributed to these contrasting results. Nevertheless, with the exception of New Truliner, the mean bond strength values ranged from 8.42 to 16.53 MPa and appear to be adequate for relining complete dentures even after a clinical service period of 1 year;[1,3] however, it has been observed that the lower dentures were considerably more prone to surface loss of reline material than the upper dentures, regardless of the material used.[1] Thus, longer clinical investigations are needed to evaluate the long-term reliability of adhesive strength between autopolymerizing relining resins and denture base materials. In addition, other properties such as staining, discoloration, and irritation to oral tissue are also important for the clinical success of the relining technique and should be investigated.

Conclusions

Within the limits of this in vitro study, the following conclusions were drawn:

1. After 90 days of water immersion, Ufi Gel Hard and Tokuso Rebase Fast showed a significant increase in mean shear bond strength compared with control ($p < 0.001$) and the 7-day immersion period ($p = 0.035$).
2. Lucitone 550 specimens immersed in water for 90 days exhibited significantly lower mean shear bond strength than those immersed in water for 7 days ($p < 0.001$).
3. The shear bond strengths of Kooliner and New Truliner were not significantly affected by long-term water immersion.
4. For Lucitone 550 and Ufi Gel Hard, failures were mainly cohesive, whereas Tokuso Rebase Fast, Kooliner, and New Truliner failed adhesively.

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