Bond Strength of Hard Direct Reline Materials to Heat-cured Acrylic Denture Base after Immersion in Denture Cleansers

Abstract

**Background:** Immersion-type denture cleansers are commonly used for denture hygiene maintenance. Hence, it is crucial to investigate the effect of denture cleansing solutions on bond strength between direct relining materials and denture base resin. **Aims:** This in vitro study aimed to determine the effect of denture cleansers on bond strength between direct hard relining materials and denture base resin. **Materials and Methods:** Cylindrical columns of hard-liners (Hard GC Reline, TDV Cold Liner Rebase, Tokuyama Rebase II Fast) were bonded to heat-polymerized denture base resin. A total of fifty specimens were fabricated for each relining material and divided into five groups (n = 10): Group I (control): No solution was used; Group II: Specimens were stored in distilled water for 60 days; Groups III, IV, and V: Specimens were stored in distilled water for 60 days with daily immersion in either sodium hypochlorite, calgon + sodium hypochlorite, or dentipur tablet for 5 min. The shear bond strength was examined at a cross-head speed of 1 mm/min. Failure mode was evaluated by stereomicroscope. **Statistical Analysis:** Data were analyzed by two-way ANOVA and Chi-square test (α=0.05). **Results:** The results showed no significant interaction between the direct hard-liners and denture cleansers (P = 0.119). Hard GC Reline had the highest bond strength, followed by Tokuyama Rebase II Fast, and then, TDV Cold Liner Rebase. No significant difference existed in bond strength between samples immersed in water and cleansers or between the cleansers themselves. Hard GC Reline had more mixed failure mode compared to TDV Cold Liner Rebase and Tokuyama Rebase II Fast. There was a significant correlation between mixed mode of failure and higher values of bond strength (P = 0.008). **Conclusions:** Within the limitations of the present study, denture cleansing solutions could not significantly influence the bond strength between hard direct liners and denture base resin.

Keywords: Denture base resin, denture cleanser, hard direct relining material, shear bond strength

Introduction

Relining is a procedure used to resurface the intaglio side of complete, partial and immediate dentures, and maxillofacial prostheses.[1] Because of the gradual and progressive resorption of the edentulous ridge, existing removable prostheses need to be relined to improve their adaptation, stability, retention, and support.[2-4] There are two types of relining procedures: Direct (chairside) that uses autopolymerized resin materials and indirect, which uses heat-cured liners in the laboratory setting.[5,6]

The chairside relining procedure is faster and easier than heat-processed systems. This procedure does not result in warpage or dimensional change to the prostheses, and the patient is not without the denture during the laboratory procedure.[1,7] There are two types of direct liners: Hard and soft (resilient). Soft liners are developed for sensitive mucosa, areas of injury, trauma, and during the healing period. Hard relining materials have suitable physical and mechanical characteristics and can be used in high-stress areas where high strength is needed.[8-9]

The relined denture consists of two layers of different materials with an interface that forms a composite laminate structure.[10] An adequate bond between the liner and denture base is essential. A weak bond can result in microbial accumulation at the interface of two materials, staining, and delamination of the liner.[2,11] The bond strength between the denture base and liner can influence the overall mechanical strength of the relined denture.[12-14] Proper plaque control is essential for oral health maintenance and hygiene in patients that use removable prostheses.[15-17]
Commonly used methods for denture cleaning include mechanical appliances (brushing or ultrasonic) and immersion-type or chemical cleansers. Denture cleansers can be categorized on the basis of their chemical composition: Alkaline hypochlorites, alkaline peroxides, acids, enzymes, and disinfectants. These cleansers can remove stains, reduce plaque formation, and inactivate microorganisms. For elderly patients who have limited movement, immersion of the dentures in a proper cleansing solution is the method of choice for plaque control and good oral hygiene.

Compatibility between liners and cleansers and the effect of long-term application of immersion type chemical agents on bond strength between reline material and denture base resin should be considered to avoid adverse effects. The purpose of this study was to evaluate shear bond strength between a heat-processed acrylic resin and three different types of hard direct liners after daily immersion in three different cleansing solutions. The null hypothesis was that denture cleansers could not affect the bond strength between hard-liner and denture base resin.

**Materials and Methods**

Materials used in this in vitro study included a heat-processed denture base acrylic resin and three hard chairside liners. Table 1 lists their brands, chemical compositions, recommended mixing ratio, and mode of polymerization. Machined brass spacers were fabricated with dimensions of 8 mm in diameter and 10 mm in height. Then, spacers were invested in very high viscosity silicone (Coltene Speedex Putty, Coltene AG, Altstatten, Switzerland) impression material and further supported with type IV dental stone. Silicone facilitates the removal of heat-cured specimens in addition to metal spacers from the flask.

The flasks were opened, and the metallic cylinders were removed. Denture base resin was mixed, packed, and cured according to instructions recommended by the manufacturer. After polymerization, the specimens were retrieved from the flasks. The defective specimens were excluded, then the remaining specimens were stored in distilled water for 50 ± 2 h at 37°C ± 1°C. A total of 150 denture base specimens were fabricated. Next, the flash was trimmed, and then, the top and bottom surfaces of the specimens were smoothed with 240-grit silicon carbide paper. Finally, the surfaces were washed with distilled water and dried.

A total of fifty specimens were bonded to each of the three types of hard-liners (Hard GC Reline, Tokuyama Rebase II Fast, TDV Cold Liner Rebase). The specimens surfaces were treated according to the manufacturer’s instructions for each liner. For the Hard GC Reline, the surface was wet with the bonding agent in the kit and air dried. For the Tokuyama Rebase II Fast, the adhesive was applied and left to dry for 20 seconds. For the TDV Cold Liner Rebase, the bonding surface was left untreated because there was no adhesive available in the kit. However, two layers of glaze were applied over the liner after bonding and removal of the tube. Afterward, a masking tape with a 5 mm diameter circular hole was placed on the surface of each specimen, and a plastic tube (4 mm internal diameter and 5 mm height) was placed on the hole. The liners were mixed and inserted into the tube.

After polymerization of the liners, the plastic tube was cut and removed with a blade. The specimens from each lining

| Material                  | Type of polymerization | Powder/liquid ratio | Composition | Manufacturer                  | Polymerization cycle |
|---------------------------|------------------------|---------------------|-------------|-------------------------------|----------------------|
| Meliodent                 | Heat-cured            | 35 g/1 ml           | PMMA, benzoyl peroxide, MMA, EGDMA | Heraeus Kulzer, Hanau, Germany | 90 min at 73°C, 30 min at 100°C |
| Hard GC Reline            | Self-cured polymer    | 1.8 g/1 ml          | Bonding: MMA, PEMA, benzoyl peroxide, silicon oxide, PEMA, HEMA, acetone, MMA, 1,6-HDMA, AAEM, 1,9-nonanediol dimethacrylate | GC America Incorporation, Alsip IL, USA | 5-6 min in mouth |
| Tokuyama Rebase II Fast   | Self-cured polymer    | 6.02 g/2.49 ml      | Adhesive: Ethyl acetate, acetone, MMA, DMPT, BHT, isobutyl methacrylate | Tokuyama Dental Corporation, Tokyo, Japan | 5.5 min at room temperature |
| TDV Cold Liner Rebase     | Self-cured polymer    | 1.2 g/1 ml          | Glaze: PMMA, ethyl acetate, MMA, benzoyl peroxide, starch and organic pigments | TDV Denal Ltda, Pomerode, Brasil | 5 min in mouth |

PMMA=Polymethyl methacrylate, MMA=Methyl methacrylate, EGDMA=Ethylene glycol dimethacrylate, PEMA=Polyethyl methacrylate, 1,6-HDMA=1,6-hexanediol dimethacrylate, HEMA=2-hydroxyethyl methacrylate, AAEM=2-(acetoacetoxy) ethyl methacrylate, EMA=Ethyl methacrylate, DMPT=Dimethyl p-toluidine, BHT=Butylated hydroxytoluene
material were divided into five groups (ten specimens per group). The first group (I) was the control, which was not immersed into any solution. In the second group (II), the specimens were stored in distilled water for 60 days. Specimens in the remaining groups (III, IV, and V) were stored in distilled water. These specimens were immersed in denture cleansers [Table 2] for 5 min once per day until the end of the 60 days. Fresh cleanser solutions were prepared each day, and the distilled water was changed daily.

All immersion procedures were carried out at room temperature. After the immersion period, the specimens were dried with paper towel. Each specimen was mounted in a cubic box of autopolymerized resin for placement in the testing machine. Shear bond test was performed using a universal testing machine (Zwick-Roell Z2020, Zwick GmbH, Ulm, Germany) at a cross-head speed of 1 mm/min [Figure 1]. Shear bond strength was calculated using the following equation: \( F = \frac{N}{A} \), where \( F \) is the shear bond strength (MPa), \( N \) is the load applied with the knife-edge blade of the testing machine until fracture (Newton), and \( A \) is the surface area of adhesion.

Once the bond broke, the remaining surfaces of the denture base specimens were evaluated using a stereomicroscope (Bestscope BS-3060, Best Scope, Beijing, China) at \( \times 25 \) magnification to determine the bonding failure mode. Fracture that occurred at the junction of two materials was considered an adhesive fracture. The presence of any denture liner on the surface of denture base was recorded as mixed failure.

Data from the shear bond test were statistically analyzed using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). The two-way ANOVA was performed to assess the effect of different hard-liners and cleansers on bond strength. The Tukey test was used for pairwise comparisons (\( \alpha = 0.05 \)). The Chi-square test was used to analyze the mode of failures. The \( t \)-test was used to analyze the relationship between bond strength values and mode of failure.

### Results

Table 3 lists the mean ± standard deviation of the shear bond strength values. The results of two-way ANOVA [Table 4] indicated no significant interaction between hard-liners and denture cleansers for shear bond strength (\( P = 0.119 \)). Without considering the effect of the immersion condition, the type of hard reline material had a significant influence on shear bond strength (\( P < 0.001 \)). We observed the greatest bond strength between the Hard GC Reline and denture base followed by the Tokuyama Rebase II Fast and then TDV Cold Liner Rebase.

No significant difference existed in bond strength between immersion in water and denture cleansers or between the different denture cleansers. However, the control

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Table 2: Denture cleansers used in the present study

| Material            | Ingredients                                                                 | Solution fabrication | Manufacturer                |
|---------------------|------------------------------------------------------------------------------|----------------------|-----------------------------|
| Dentipur           | Potassium caroate, sodium carbonate, citric acid, glucose, VP/VA copolymer, sodium lauryl sulfate, sodium lauryl sulfonate | A tablet in 100 ml water at 35°C | Helago-Pharma GmbH, Erfstadt, Germany |
| Sodium hypochlorite | One part of hypochlorite solution 5% diluted in 3 parts of water              |                      | Nirouchlor Company, Isfahan, Iran |
| Sodium hypochlorite + calgon (sodium hexametaphosphate) | 2 teaspoons of calgon and 1 teaspoon of hypochlorite 5% in half a glass of water |                      | Kimia Mavad Chemicals, Isfahan, Iran |

Table 3: Shear bond strength mean values and standard deviations of the tested hard-liners

| Material               | Control (I) | Water (II) | Hypochlorite (III) | Calgon + hypochlorite (IV) | Dentipur (V) | Total     |
|------------------------|-------------|------------|-------------------|---------------------------|--------------|-----------|
| Tokuyama Rebase II Fast| 8.26±1.61   | 8.48±1.54  | 7.26±1.76         | 6.83±1.59                 | 7.21±0.99    | 7.61±1.60 |
| TDV Cold Liner Rebase  | 7.13±1.09   | 6.35±1.80  | 5.90±1.68         | 5.68±0.95                 | 6.74±1.65    | 6.36±1.51 |
| Hard GC Reline         | 10.14±1.85  | 9.41±1.06  | 9.92±1.89         | 9.35±1.19                 | 8.00±0.97    | 9.39±1.57 |
| Total                  | 8.51±1.96   | 8.08±1.95  | 7.69±2.41         | 7.29±1.98                 | 7.29±1.32    | 7.78±1.99 |

No significant interaction was found between reline materials and cleansers.
group had significantly higher values compared to the calgon + sodium hypochlorite and dentipur solutions. No statistically significant difference existed among the other groups.

Table 5 lists the mode of failures observed between the hard-liner and denture base. Without considering the effect of conditioning solution, we observed mostly mixed fractures for the Hard GC Reline failures. However, the majority of failures for Tokuyama Rebase II Fast and TDV Cold Liner Rebase were adhesive (P < 0.001). The t-test results indicated that samples with adhesive fracture mode had significantly lower bond strength. A significant relationship existed between mixed mode of failure and higher amounts of bond strength (P = 0.008). Without considering the effect of the lining material, there was no significant relationship between solution and mode of failure (P = 0.2).

Discussion

The present study aimed to determine the effect of denture cleaners on bond strength between hard reline material and denture base resin. The results of the present study confirmed the null hypothesis because the interactions between the type of denture liner and cleanser solutions were not significant.

Hard chairside reline materials allow the practitioner to reline removable complete and partial dentures directly in the patient’s mouth to improve their adaptation. A common problem is failure in adhesion between denture base resin and hard-liner. Relined dentures are made from two different layers of materials and can only function well when there is a proper bond between the two layers.

When a polymer comes into contact with a monomer or solvent, the monomer diffuses into the resin and forms a swollen layer. In the relining procedure, after formation of the swollen layer, the liners monomer and cross-linking agent diffuse into the resin surface, where it polymerizes and forms an interpenetrating polymer network. The bond strength depends on the depth of the swollen layer.

Denture hygiene is of tremendous importance because bacterial and yeast plaque may result in infection. Oral candida infections in debilitated denture wearers may become a systemic fatal infection. Chemical cleansing is usually joined with mechanical brushing for better denture plaque control. A sodium hypochlorite solution removes stain, mucin and organic substances, prevents calculus formation by dissolving an organic matrix of plaque, and disintegrates microbial plaque. At the 0.5% concentration, it can destroy Candida albicans and reduce microorganisms. Calgon is a glassy phosphate and water softener. The phosphate content of calgon provides proper protection for metallic components against the corrosive effects of a hypochlorite solution. In addition, phosphates have wetting and emulsifying effects, the ability to remove metallic stains and are widely used in cleaning products. A mixture of one teaspoon of sodium hypochlorite and two teaspoons of calgon effectively eliminates calculus and stains from dentures. Effervescent tablets are immersion type products in which the peroxide content releases oxygen bubbles that provide both mechanical and chemical cleansing for dentures.

There is no general consensus in the literature regarding a test method to evaluate the bond strength between a denture base and reline materials. In the current study, the shear load test was used because it applies the force directly to the reline base interface. A number of authors used

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**Table 4: Results of two-way ANOVA for shear bond strength values**

| Source                          | SS       | df | MS   | F       | P  |
|---------------------------------|----------|----|------|---------|----|
| Material                        | 225.005  | 2  | 112.502 | 50.721 | <0.001 |
| Cleanser solution               | 32.578   | 4  | 8.145 | 3.672   | 0.007 |
| Material × cleanser solution    | 29.085   | 8  | 3.636 | 1.639   | 0.119 |

SS=Sum of square, MS=Mean square error

**Table 5: Mode of failures and their percentages**

| Solution       | Hard GC Reline | Tokuyama Rebase II Fast | TDV Cold Liner Rebase | Total   |
|----------------|----------------|-------------------------|-----------------------|---------|
| Control        | 50% mixed      | 20% mixed               | 20% mixed             | 30% mixed |
| Water          | 90% mixed      | 10% adhesive            | 10% adhesive          | 60% mixed |
| Calgon + hypochlorite | 80% mixed       | 20% adhesive            | 60% adhesive          | 43.3% mixed |
| Hypochlorite   | 90% mixed      | 10% adhesive            | 60% adhesive          | 43.3% mixed |
| Dentipur      | 50% mixed      | 50% mixed               | 30% mixed             | 50% mixed |
| Total          | 72% mixed      | 28% mixed               | 42% mixed             | 47.3% mixed |

A number of authors used
In the present study, Hard GC Reline had the highest bond strength followed by Tokuyama Rebase II Fast. TDV Cold Liner Rebase had the lowest bond strength. Mutluay and Ruyter reported that Hard GC Reline had a high-bond strength. The authors suggested that this finding might be attributed to the presence of methyl methacrylate (MMA) in the bonding agent since small MMA molecules could properly diffuse into the denture base polymer and form an adequate swollen layer. TDV Cold Liner Rebase demonstrated the lowest bond strength because this material did not have any bonding agent available in the kit. Studies showed that bonding agents had the capability to increase bonding between a hard-liner and the denture base resin.

The results of the present study showed a higher mean shear bond strength of specimens in the control groups compared to the water groups; however, there was no statistically significant difference observed between the water and control groups. Cucci et al. observed that the bond strength of Kooliner Hard Denture Reline did not significantly change after 30 days of water immersion whereas for Duraliner II, the bond strength decreased over the same immersion period. Ohkubo et al. reported no significant correlation between bonding strength and immersion period of Kooliner Hard Denture Reline. Azevedo et al. reported that after 90 days of water immersion, the shear bond strength between Tokuso Rebase Fast, Ufi Gel Hard, and the denture base increased. Kooliner and New Truliner did not show any significant changes.

Immersion of polymeric resin in water results in absorption of water molecules between the polymeric chains, which forces them apart and decreases bonding between the chains. The absorbed water molecules within these polymeric chains may act as plasticizers and reduce the bond strength. However, cross-linking agents in reline materials such as 1,6-hexanediol dimethacrylate, which is present in Hard GC Reline decreases their water sorption. The results of the current study have shown a statistically significant difference in the mean shear bond strength among three different hard-liners. In other studies, investigators reported different bond strengths with different liners. They concluded that the chemical composition of the liner could affect the bond strength between the denture base and hard reline material.

In self-cured resins, due to the low degree of conversion of monomer to polymer, all monomer molecules are not used; hence, the residual monomer remains in the structure. Continuous polymerization, consumption of the residual monomer which acts as a plasticizer and release of the residual monomer into the solution compensate for the absorbed water effect. As a result, in the present study, immersion in water did not significantly impact the bond strength compared to the control group.

In the present study, higher mean shear bond strength of specimens immersed in water was observed compared to the specimens immersed in all three types of cleansers. However, the denture cleanser had no significant effect on bond strength compared to immersion in water. de Luna Malheiros-Segundo et al. reported that immersion in sodium perborate cleansing agent did not significantly affect the bond strength between a hard and a resilient liner to the denture base resin.

The control group had significantly higher values compared to the calgon + sodium hypochlorite ($P = 0.015$) and dentipur tablet ($P = 0.017$) solutions. This finding might be due to the effect of both immersion in water and cleanser. The diffusion of components of the cleanser solution and water molecules in the interface of the denture base and hard-liner might have a more destructive effect on bond strength compared to the effect of each individually. To identify the mechanisms of the difference in bond strength between the control and calgon + sodium hypochlorite and dentipur groups, further studies would be necessary. In the oral environment, dentures are always immersed in saliva. As a result, the main objective of this assessment was to evaluate the difference in bond strength of samples immersed in water and denture cleansers.

According to the results of the current study, adhesive was the main failure mode for both Tokuyama Rebase II Fast and TDV Cold Liner Rebase whereas the mixed mode of failure was predominant for Hard GC Reline. In agreement with Hasan et al., we observed that specimens with mixed modes of failure had significantly higher bond strength. A significant relationship existed between the adhesive mode and lower bond strength values.

In the present study, we have evaluated three types of denture cleansers and direct reline materials. Further studies should assess the interaction between other types of cleansers and direct hard-liners. We propose a longer immersion time to evaluate the long-term reliability of bond strength between direct hard-liners and denture base resins.

**Conclusions**

Within the limitations of this in vitro study, we concluded that the use of denture cleansers did not modify the bond strength between hard reline materials and denture base resin. Hard GC Reline had the highest bond strength followed by Tokuyama Rebase II Fast. TDV Cold Liner Rebase had the lowest bond strength. The adhesive mode of failure was predominant for Tokuyama Rebase II Fast and TDV Cold Liner Rebase; however, the mixed mode of failure was predominant for Hard GC Reline.
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Conflicts of interest

There are no conflicts of interest.

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