Comparative evaluation of tensile bond strength of a polyvinyl acetate-based resilient liner following various denture base surface pre-treatment methods and immersion in artificial salivary medium: An in vitro study

JACOB M. PHILIP, DHANRAJ. M. GANAPATHY, PADMA ARIGA

Abstract

Background and Aim: This study was formulated to evaluate and estimate the influence of various denture base resin surface pre-treatments (chemical and mechanical and combinations) upon tensile bond strength between a polyvinyl acetate-based denture liner and a denture base resin. Materials and Methods: A universal testing machine was used for determining the bond strength of the liner to surface pre-treated acrylic resin blocks. The data was analyzed by one-way analysis of variance and the t-test (α = .05). Results: This study infers that denture base surface pre-treatment can improve the adhesive tensile bond strength between the liner and denture base specimens. The results of this study infer that chemical, mechanical, and mechano-chemical pre-treatments will have different effects on the bond strength of the acrylic soft resilient liner to the denture base. Conclusion: Among the various methods of pre-treatment of denture base resins, it was inferred that the mechano-chemical pre-treatment method with air-borne particle abrasion followed by monomer application exhibited superior bond strength than other methods with the resilient liner. Hence, this method could be effectively used to improve bond strength between liner and denture base and thus could minimize delamination of liner from the denture base during function.

Keywords: Denture base resin, denture liner, tensile bond strength

Introduction

Resilient denture liners have been used with increasing popularity to refit the surface of complete dentures and to help condition traumatized tissues.[1] The silicon soft liners, despite various denture base surface pre-treatments, tend to have a compromised adhesive strength with the denture base in due course of time during function.[2] When immersed in water, acrylic-based denture liners undergo leaching of plasticizers and other soluble materials into water and water imbibitions, thus compromising their physical and mechanical properties. Hence, as a potential alternative, polyvinyl acetate liners can be used as a provisional denture liner intra-orally for up to 30 days. The advantages claimed are better bond to the denture base, increased comfort to the patient, non-porous nature, and improved resistance to microbial contamination. If denture base surface pre-treatments are carried out, it could greatly augment the bond strength between the denture base and the denture liner.[3]

It has been shown that the use of organic solvents increases the bond strength between denture liners and denture bases.[4-7] Chemical etchants such as monomethyl methacrylate,[6] acetone,[8,9] or methylene chloride[10,11] have been used to increase the bond strength of repair material to polymethyl methacrylate denture base.

Hence, this study was formulated to evaluate and compare the influence of various denture base resin surface pre-treatments (chemical and mechanical and combinations) on the tensile bond strength between a polyvinyl acetate-based denture liner and a denture base resin.

Materials and Methods

Hundred and forty-seven polymethyl methacrylate (PMMA) denture base resin specimens [TREVLON/INDIA] consisting of 2 rectangular blocks measuring 10 × 10 × 40 mm were prepared and divided into 3 equal categories (n = 49) representing the time of immersion in artificial saliva before measuring the bond strength. For preparation of the blocks, the method used by Duygu Sarac and Sinasi Sarac was followed.[12] The materials used in this study have been summarized in Table 1. The specimens were divided into 7 groups (n = 14) for each of the 24 hours, 1 week, and 1 month categories.
Table 1: Materials used in this study

| Material                        | Product      | Manufacturer/Country |
|---------------------------------|--------------|----------------------|
| Polyvinyl acetate resilient liner | Dinabase     | Italy                |
| Heat polymerized acrylic resin  | Trevalon     | Dentsply             |
| Acetone                         | -            | Merck                |
| Methyl methacrylate             | Cold cure    | DPI, India           |
| Sand paper, 1000 grit silicon carbide paper | Zetaplus | Zhermack Spa        |
| Alumina (50 microns) air abrasion | Basic Duo air abrasion unit | Renfert             |

Two PMMA blocks with 3 mm thick metal spacer between them was invested in denture flask using silicone rubber to allow for easy removal of the specimens from the flask. The PMMA blocks were then removed from the flask, and the surface to be bonded was pre-treated with different chemical, mechanical, and chemico-mechanical methods as mentioned in Table 2. Next, the PMMA blocks were placed back into the molds, and the polyvinyl acetate-based resilient liner (Dinabase, Italy) was packed into the space made by the brass spacer. After 10 minutes, the specimens were removed from the flap, and excess liner was carefully removed with a scalpel. Tensile bond was calculated for each specimen from the flask, and excess liner was carefully removed with a brass spacer. After 10 minutes, the specimens were removed from the flask, and excess liner was carefully removed with a scalpel. Tensile bond was calculated for each specimen until failure after 24 hours (n = 7 for each group), 1 week (n = 7 for each group), and 1 month (n = 7 for each group) of storage in artificial saliva. Universal testing machine at a crosshead speed of 5 mm/min was used for this test. Bond strength (Mpa) was calculated as stress at failure divided by the cross-sectional area of the specimen. The data was analyzed by 1-way analysis of variance and the t-test (α = .05).

Results

Figures 1, 2, and 3 show the mean tensile bond strength of the 7 groups in each of the 24 hour, 1 week, and 1 month categories.

The highest mean tensile bond strength in each of the 3 categories was obtained by the methyl methacrylate monomer with air-borne particle abrasion group, and the lowest mean tensile bond strength in each of the 3 categories was obtained by the control group.

The overall highest mean tensile bond strength from all 3 categories ranked together was obtained by the methyl methacrylate monomer with air-borne particle abrasion group tested 1 week post-bonding. The overall lowest mean tensile bond strength from all 3 categories ranked together was obtained by the control group tested 24 hours post-bonding.

Table 2: Surface pretreatments and groups

| Group | Abbreviation | Surface pretreatment                                      |
|-------|--------------|----------------------------------------------------------|
| 1     | C            | Untreated (control)                                       |
| 2     | A            | Immersion in acetone for 30 seconds                       |
| 3     | MMA          | Immersion in methyl methacrylate for 180 seconds          |
| 4     | SP           | Sand papered using 1000 grit silicon carbide paper for 5 seconds |
| 5     | APA          | Sand blasted using 50 micron alumina particles for 5 seconds |
| 6     | SPMMA        | Sand papered using 1000 grit silicon carbide paper for 5 seconds and methyl methacrylate immersed for 180 seconds |
| 7     | APAMMA       | Sand blasted using 50 micron alumina particles for 5 seconds and methyl methacrylate immersed for 180 seconds |

The results of the one-way ANOVA tests for tensile bond strength values obtained 24 hours, 1 week, and 1 month post-bonding revealed that the differences in tensile bond strength values obtained in each of the 7 groups were statistically significant.

Discussion

The results of this study show that surface pre-treatment of the denture base increases the tensile bond strength between the denture base and the polyvinyl acetate denture liner and different surface pre-treatments would have varying influences on the tensile bond strength between the denture base and the polyvinyl acetate denture liner.

Group 1 specimens (control) exhibited least bond strength. This could be due to the limited available surface area for bonding when compared to the other pre-treated groups.

Group 2 specimens pre-treated with acetone exhibited significant increase in the bond strength after immersion in artificial saliva compared to the control groups (P < .05). This is in accordance with a study conducted by Sarac et al. on a silicone-based resilient liner. Acetone, being an organic solvent, could have penetrated into the surface of the poly methyl methacrylate resin creating microvoids in the resin surface, thus increasing the surface area for the liner to bond to the denture base.

Group 3 specimens pre-treated with methyl methacrylate monomer exhibited significant increase in the bond strength after immersion in artificial saliva compared to the control groups (P < .05). This is in accordance with a study conducted by Sarac et al. on a silicone-based resilient liner. Monomer provided additional etching and increased the surface area by creating microvoids, thus increasing the surface area available for the liner to bond to the resin.
Group 4 specimens pre-treated with sandpaper exhibited significant increase in the bond strength after immersion in artificial saliva compared to the control groups ($P < .05$).

Sandpapering created micro roughness of the surface resin block, which helped to bond stronger. This is in accordance with Craig’s suggestion that a roughened acrylic denture base surface can be used in order to improve the adhesion between the denture base and resilient liner and Li Xiao-na and Zhao Yi-min’s findings in their study on silicone liners.

Group 5 specimens pre-treated with air-borne particle abrasion exhibited insignificant increase in the bond strength after immersion compared to the control groups ($P < .05$). This may be due to insufficient increase in surface area of the denture base to cause a significant increase in the bond strength when compared to the control group. This is in accordance with a study conducted by Nancy et al. and Minami H et al. for silicone-based soft liners.

Group 6 specimens pre-treated with sandpaper and monomer exhibited a significant increase in the bond strength at 24 hours (0.082 MPa) and 1 month (0.1176 MPa) and insignificant increase in bond strength at 1 week (0.1178 MPa) compared to the control groups ($P < .05$). This may be due to insufficient increase in surface area of the denture base to cause a significant increase in the bond strength when compared to the control group after 1 week of immersion. The latent polymerization of unreacted units in the resilient liner may be responsible for the significant increase in tensile bond strength when measured after 1 month of immersion. Sand papering caused microvoids and monomer acted as a superficial solvent of the poly methyl methacrylate resin, which enhanced bond strength.

Group 7 specimens pre-treated with sandblasting and monomer exhibited significant increase in the bond strength after immersion in artificial saliva compared to the control groups ($P < .05$). Sandblasting caused microvoids and monomer acted as a superficial solvent of the poly methyl methacrylate resin, which enhanced bond strength.

Among the chemical methods, pre-treatment with monomer (Group 3) exhibited higher bond strength of (0.054 MPa) than acetone group (Group 2) (0.043 MPa) when evaluated at 24 hrs. This is in accordance with a study conducted by Sarac et al. on a silicone-based resilient liner. One week results showed (0.114029 MPa) and (0.116186 MPa), and 1 month results were (0.113871 MPa) and (0.116014 MPa), respectively, after immersion in the artificial saliva.

Among the mechanical methods, air-borne particle abrasion group (Group 5) exhibited higher bond strength (0.0727 MPa) than sand paper group (Group 4) (0.0615 MPa) within 24 hrs. When 1 week samples were tested, bond strength was (0.1182 MPa) and (0.1193 MPa), respectively. One month samples exhibited bond strength of (0.1181 MPa) and (0.1192 MPa), respectively.

The results of mechano-chemical method showed highest
bond strength of (0.111 Mpa) for air-borne particle abrasion with monomer group when tested with in 24 hrs and sandpaper with monomer group exhibited (0.082 Mpa). One week results exhibited (0.131 Mpa) and (0.1178 Mpa) and 1 month exhibited (0.130 Mpa) and (0.1176 Mpa), respectively. All surface pre-treated specimens immersed in artificial salivary medium for a period of 1 week showed 118 - 270% increase in bond strength compared to specimens at 24 hours. This could be attributed to the latent polymerization of unreacted units in the resilient liner. The tensile bond strength evaluation after a period of 1 month was analogous with the result obtained after 1 week. This may be attributed to less salivary sorption and resultant microleakage and subsequent delamination of the poly vinyl acetate denture liner.

Among the various methods of pre-treatment of denture base resins, it was inferred the mechano-chemical pre-treatment method with air-borne particle abrasion followed by monomer application exhibited superior bond strength than other methods with the resilient liner. Hence, this method could be effectively used to improve bond strength between liner and denture base and thus could minimize delamination of liner from the denture base during function.

There are few limitations pertaining to this study. This is an in vitro study and hence some variations might be experienced when tested under in vivo conditions owing to fluctuations in the pH of saliva, varying concentrations of ions in the saliva, presence of immunoglobulin’s and serum markers in the saliva, different occlusal schemes, use of disinfectants and stain removers during denture maintenance. These factors could modify bond strength during functions.

This study opens new scope for further research such as evaluation of the effect of various denture base surface pre-treatments on other properties of the polyvinyl acetate denture liner such as water sorption, co-efficient of thermal expansions, creep, dynamic modulus, and resilience of the liner. Several investigators[14] have microscopically examined the nature of the interface between conventional resilient liners and the denture base materials. There is a need for microscopic evaluation of bonding behavior of polyvinyl acetate denture liner with pre-treated denture base.

Conclusion

Within the limitations of this in vitro study, the following conclusions were drawn:
1. Pre-treating the surface of a denture base before application of a polyvinyl acetate denture liner increased the tensile bond strength between the denture base and the liner compared to untreated denture bases.
2. Tensile bond strength between the denture base and the polyvinyl acetate denture liner showed higher values at 1 week post-bonding when compared to measurements made after 24 hours and 1 month post-bonding.
3. Among the experimental groups, the highest tensile bond strength measurements were obtained when the denture base was pre-treated with air-borne particle abrasion followed by monomer immersion.

References

1. Fuji K, Arikawa H, Kanie T, Shinohara N, Inoue K. Effect of photo-irradiation on hardness of soft lining materials for denture base. J Oral Rehabil 2002;29:744-8.
2. Hayakawa I, Keh ES, Morizawa M, Muraoka G, Hirano S. A new polyisoprene-based light-curing denture soft lining material. J Dent 2003;31:269-74.
3. Leles CR, Machado AL, Vergani CE, Giampaolo ET, Pavarina AC. Bonding strength between a hard chairside reline resin and a denture base material as influenced by surface treatment. J Oral Rehabil 2001;28:1153-7.
4. Shen C, Colaizzi FA, Birns B. Strength of denture repairs as influenced by surface treatment. J Prosthet Dent 1984;52:844-8.
5. Curtis DA, Eggleston TL, Marshall SJ, Watanabe LG. Shear Bond strength of visible-light-cured resin relative to heat-cured resin. Dent Mater 1989;5:314-8.
6. Vallittu PK, Lassila VP, Lappalainen R. Wetting the repair surface with methyl methacrylate affects the transverse strength of repaired heat-polymerized resin. J Prosthet Dent 1994;72:639-43.
7. Arima T, Nikawa H, Hamada T, Harsini A. Composition and effect of denture base resin surface primers for relining acrylic resins. J Prosthet Dent 1996;75:457-62.
8. Rached RN, Del-Bel Cury AA. Heat-cured acrylic resin repaired with microwave-cured one: Bond strength and surface texture. J Oral Rehabil 2001;28:370-5.
9. Rached RN, Powers JM, Del Bel Cury AA. Repair strength of autopolymerizing, microwave, and conventional heat-polymerized acrylic resins. J Prosthet Dent 2004:92:79-82.
10. Nagai E, Otani K, Satoh Y, Suzuki S. Repair of denture base resin using woven metal and glass fiber: Effect of maleic chloride pretreatment. J Prosthet Dent 2001;85:496-500.
11. Minami H, Suzuki S, Minesaki Y, Kurashige H, Tanaka T. In vitro evaluation of the influence of repairing condition of denture base resin on the bonding of autopolymerizing resins. J Prosthet Dent 2004;91:184-70.
12. Sarac D, Sarac YS, Basoglu T, Yapici O, Yuzbasioğlu E. The evaluation of microleakage and bond strength of a silicone-based resilient liner following denture base surface pretreatment. J Prosthet Dent 2006;95:143-51.
13. Craig RG. Restorative dental materials. 8th ed. St Louis: CV Mosby; 1989. p. 542-4.
14. Li XN, Zhao YM. Effect of surface treatment on the bonding of silicone elastomer to acrylic resin. J US -China Med Sci 2008:5:54-8.
15. Jacobsen NL, Mitchell DL, Johnson DL, Holt RA. Lased and sandblasted denture base surface preparations affecting resilient liner bonding. J Prosthet Dent 1997;78:153-8.
16. Amin WM, Fletcher AM, Ritchie GM. The nature of interface between PMMA denture base materials and soft lining materials. J Dent 1981:9:336-46.