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Original Research

Effect of various chemicals on the bond strength of acrylic tooth and denture base -An In-vitro comparative study

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Abstract:

Background: Debonding of acrylic teeth from the denture base is a common problem. Certain clinical conditions like ridge prominence leads to excess trimming of acrylic teeth and base, resulting in a weak interface. The denture base polymer de-bonds adhesively in the region of the highly cross –linked matrix of the teeth. To compare the effect of different chemical surface treatments on the bond between cross-linked acrylic teeth and different types of denture base material.

Materials & Methods: A total of 180 wax specimens were fabricated and divided into 3 groups: Heat-cure, high impact heat-cure, flexible denture base material bonded to acrylic teeth. Each group was further subdivided into 6 subgroups with 10 specimens each according to the surface treatment ofthe ridge lap area: control, monomer, acetone 99%, chloroform 99%, acrylic adhesive cyanoacrylate, ethyl acetate 99%. After processing, specimens were tested for bond strength using a universal testing machine. The resulting bond strengths were recorded, statistically analyzed and compared.

Results: Among all the 3types of denture base resins, high-impact heat-cure denture base resin gave highest bond strength. There was no bonding of teeth with flexible denture base material. Chemical surface treatment of acrylic teeth with ethyl acetate gave highest bond strength followed by control, chloroform, acetone and cyanoacrylate groups.

Conclusion: Among all the 3types of denture base materials, high-impact heat-cure denture base resin gave highest bond strength with ethyl acetate surface treatment. Simple and quick tooth chemical surface treatment with ethylacetate could be an effective option in decreasing bonding failures and also avoid repeated denture repairs improving patient satisfaction.

Key Words: Acrylic tooth, bond strength, denture base resin, fracture load

Introduction

Acrylic resin teeth for dentures are preferred over porcelain teeth because of its ability to bond chemically to the denture base resin.[1] Recent advances lead to the introduction of highly cross-linked acrylic teeth with better fracture resistance, abrasion resistance and stain resistance.[2] But, on the other hand its bonding ability to denture base resin was found to be reduced.[3]

Several methods have been employed to enhance the bonding of acrylic resin teeth to denture bases which can be categorized into: Mechanical and Chemical modification of ridge lap area[4,5] or a combination of both.

Various chemical surface treatments using monomer,[4] non-polymerizable solvents,[6] dissolved Poly methyl methacrylate,[7] combination of above[8] or adhesives are comparatively less time consuming, and they improve bonding to a satisfactory extent. Monomer plasticizes the surface of denture teeth and diffuses into the denture tooth acrylic resin. Upon polymerization, an interwoven network of polymer chains that unites the denture base to the resin tooth is formed.[4] Monomer has been used with solvents such as dichloromethane or tri-chloromethane with the anticipation that the solvent would enhance the monomer diffusion and polymer network formation.[8] Solvents like ethyl acetate and acetone were used as surface preparation agents to increase the bond strength for denture repair.[9,10]

The purpose of this study was to compare the bond strength of cross-linked acrylic teeth to three types of denture base resins after different chemical surface treatments i.e. monomer,[4] acetone 99%, chloroform 99%, cyanoacrylate and ethyl acetate 99%.

Materials and Methods

This study was undertaken to evaluate the bond strength of 3 denture base materials namely, heat cure denture base resin (Dental products of India Ltd, 9, Wallace street, Mumbai – 400 001), high impact denture base resin (Travelon HI, Dentsply International, 221, W. Philadelphia street, York, PA, USA), flexible denture base material (Valplast, Mfd in USA by ValplastInt Corp, Long Island City, NY 111106) to cross linked, solvent resistant type of acrylic teeth (premadent teeth, upper right central incisors, mould M1, shade 23; Mfd by Super Dental Products, Wazipur area, Delhi) and the effect of various chemical surface treatments of the ridgelap area and on the tooth denture base bond strength.

Test specimens were prepared simulating clinical condition, as described in Japanese Standards Association 6506 (1989).[6] Master specimen was prepared by aligning the long axis of the selected anterior central incisor acrylic teeth at 45^0 to the base of a wax block, of size 10mmX10mmX30mm, with ridge lap area contacting the base.[6]A metal die was fabricated using the master specimen (Figure 1).

Figure 1: Master Specimen.

Figure 2: Silicone Mold.

Figure 3: Wax Specimen.

Silicone mold (Figure 2) was fabricated by taking the impression of the metal die. Teeth of same brand and mold size were placed in the silicone mold and molten wax was flown into it to form the base of the test specimen. Angulation of the tooth in each specimen was measured using a profile projector.

A total of 180 maxillary right central incisor teeth of same brand and mold size M1, shade 23 were used. 180 wax test specimens (Figure 3) were prepared and were divided into 3 main groups of 60 each, for being processed with heat cure, high impact heat cure and flexible denture base resins using teeth. Each group of 60 specimens were further divided into 6 subgroups control, monomer, acetone, chloroform, cyanoacrylate and etylacetatewith 10 specimens in each. Specimens were flasked (Figure 4) and dewaxing was done (Figure 5). For each respective sub-group surface treatment of ridge lap area was done with a fine tip painting brush as follows (color plate7):'a' - No chemical surface treatment (control group), 'b' - surface treatment with monomer for 180 sec,[38]'c' - Chemical surface treatment with acetone for 30 sec[10], 'd' - Chemical surface treatment with chloroform for 2 min[8], 'e' - Chemical surface treatment acrylic adhesive cyanoacrylate, 'f' - Chemical surface treatment with ethyl acetate for 2 min.[9]

Denture resins were packed and cured according to the manufacturer's directions. After retrieval and finishing

Figure 4: Investing of Wax Specimen.

Figure 5: Surface Treatment of Ridge Lap Area.

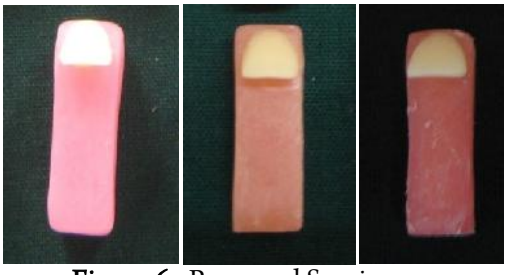


Figure 6: Processed Specimens.

(Figure 6), angulation of each specimen was again measured with profile projector and specimens with any change in angulation were discarded.

Processing of the specimens with flexible denture base material:

The wax blocks were flasked in special aluminium flasks using dental stone and with sprues attached to each wax block. Dewaxing was done followed by application of chemicals. The valplast resin cylinder is heated at 290°C for 11 minutes using the valplast digital furnace. While valpalst is melting, close and tighten the flasks and the flasks were positioned in the super-injector press. Molten valplast material is injected using the Super-Injector Press. The flask was allowed to cool for at least 30min and the specimens were retrieved.

The prepared specimens were subjected to load testing using Hounsfield Universal Testing Machine (UNITEK 95100 Computerised UTM, Capacity 10 tons, Model: FIE Indian make) at Naval Science and Technological Ltd., Visakhapatnam (Figure 7). Each test specimen was held securely in a specially fabricated stainless steel jig in order to avoid any change in position at the time of testing (Figure 8). It was aligned such that when moved downwards it applies a load on the palatal surface of the specimen denture teeth[6] (Figure 9). A cross head speed of 1 mm/min was used for testing the bond strength. All the tests were carried out under uniform atmospheric conditions of $23^0 \pm 1^0$ C temperature. Load was applied till the denture teeth separated from the denture base resin. The resulting bond strengths were recorded and

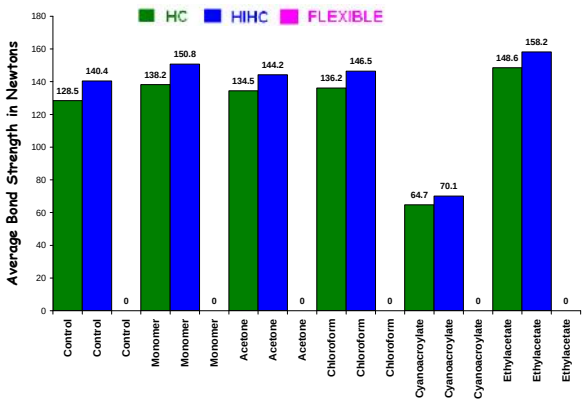
Figure 7: Hounsfield Universal Testing Machine.

Figure 8: Specimen Held in Metal Jig.

Figure 9: Testing Specimen.

Table 1: Results of bond strengths after different chemical surface treatments.

	Ethylacetate	monomer	chloroform	Acetone	Control	Cyanoacrylate
Heat cure material	148.6	138.2	136.2	134.5	128.5	64.7
High impact material	158.2	150.8	146.5	144.2	140.4	70.1
Flexible material	0	0	0	0	0	0
Units: Bond strength in Newtons						



Graph 1: Comparison of bond strengths after different chemical surface treatments.

statistically analyzed.

For all specimens, the interface where failure occurred was inspected. The interface failures were classified into 3 categories: Adhesive: if fracture occurred at the tooth resin interface, Cohesive: if fracture occurred within resin or tooth exclusively, Mixed: if fracture occurred such that some tooth structure was left intact on the ridge lap resin surface. One of the most common types of failure in a denture is adhesive type of bond failure between the acrylic resin polymer tooth and the denture base. Failure cohesively can be construed as an evidence to increase in bond strength between the tooth and the denture base. so, cohesive and mixed failures were also taken into consideration in the study.[6,8] Descriptive statistics, Independent samples 't' test were applied when appropriate. All the statistical methods were carried out through MINITAB (version 14) software.

Results

Results showed that, among heat cure and high–impact heat-cure denture base resins, ethylacetate subgroup showed the highest bond strength followed by monomer, chloroform, acetone, control and cyanoacrylate subgroups respectively (Table 1, Graph 1). There was no bonding of the teeth with flexible denture base material irrespective of the chemical surface treatment.

T-test between Heat cure and High impact heat cure groups shows significant difference between the bond strengths of heat cure and high impact heat cure denture base material for all subgroups. There was no bonding of chemically treated teeth with flexible denture base material, so could not be compared with heat cure and high impact heat cure denture base material.

Discussion

There are variety of methods for preparing specimens and testing bond strength, designed to comply with various national standards (e.g. ISO 3336, 1993; ANSI/ADA 15, 1985; AS 1626, 1974; BS 3990, 1980; SABS 1342, 1982; DIN 13907, 1983; DIN 13914, 1987; JIS T 6506 1989), this may be part of the reason for the sometimes conflicting result.[12,13] The standard specifications, ADA 15 and IS0 3336(and those standards based on them), are open to criticism in their approach to determining the bond strength of plastic denture teeth.[12,13] In the former, posterior teeth only can be evaluated because of the specimen dimensions, yet, in practice, anterior teeth are more prone to be displaced from the denture base. Further, the need to machine the tensile specimen subsequent to processing would introduce stresses at the tooth-base interface and so adversely effect the test results. This fact has been recognized in the study by Clancy et al. (1991) where a two stage approach in specimen preparation was adopted.[11]Using the method described in IS0 3336 a more clinically correct test specimen is produced. However, the tensile shear loading system employed in this method together with the varying tooth bonding surfaces does not allow quantitative results to be obtained. The Japanese standard JIS T 6506 attempts to overcome this problem by using a single tooth form as its specimen.[12]The method of Japanese Standard for Acrylic Resin Teeth (JIS T 6506, 1989) was used for the study as it simulates clinical situation in the mouth where the denture is subjected to a variety of forces over a period of time.[13]

and contribution of the legislation, to create a healthy environment.[13] The attitude of smokers was less as compared to non smokers towards regulatory approach and the results were consistent with study conducted by Chaudhary et al in 2010.[10]

It is also seen in other studies that an absolute prohibition on smoking tends to reduce the number of smokers.[14] In the present study a higher frequency of participants (23%) had decreased the frequency of smoking after the introduction of this legislation and the results were higher as observed by Chaudhary et al.[10] Mostly students answered that it was good to ban smoking in public places like buses, trains etc. However these findings were not consistent with the previous study.[13]

Effect of different chemical surface treatments on bondstrength

Results showed that treating the ridge lap area of cross-linked acrylic teeth with ethyl acetate gave highest bond strength (148.6N with heat cure denture base material and 158.2Nwith high impact heat cure denture base material). Ethyl acetate is an organic and non-polymerizable solvent with potential to swell the surface and permit diffusion of the polymerizable material thereby increasing bond strength compared to control group with no surface treatment.[9]

Treating the ridge lap area of cross- linked acrylic teeth with monomer gave the next highest bond strength (138.2N with heat cure denture base material and 150.8N with high impact heat cure denture base material). On a theoretical basis, the polymerizable monomer plasticizes

the surface of denture teeth and diffuses into the denture tooth acrylic resin. Upon polymerization, an interwoven network of polymer chain that unites the denture base to the resin tooth is formed. Bond strength depends on the degree of penetration of the monomer and the strength of this interwoven polymer network formed thereafter.[6]

Treating the ridge lap area of cross- linked acrylic teeth with chloroform and acetone gave the next highest bond strength(136.2N with heat cure denture base material and 146.5N with high impact heat cure denture base material for chloroform and 134.5N with heat cure denture base material and 144.2Nwith high impact heat cure denture base material for acetone). Chloroform is a non-polymerizable solvent which appears to facilitate the swelling of the tooth polymer which, if cross-linked, would be slow with MMA alone, and thus MMA diffusion. This presumably improves the extent and quality of the interpenetrating networks when polymerization is completed. Higher bond strength of acetone subgroup when compared with control may be attributed to superior adhesion as a result of monomer infiltration into the pits and cracks formed by acetone treatment of the ridgelap area.

Bond strength with cyanoacrylate adhesive surface treatment (64.7N with heat cure denture base material and 70.1Nwith high impact heat cure denture base material) was found to be even less than that of control group. This may be because the set adhesive forms a layer at the interface of tooth and denture base resin which inhibits diffusion of monomer across the interface to form an interpenetrating polymer network. Thus cyanoacrylate interferes with chemical adhesion between the denture base and the tooth. Results showed that bond strength was unsatisfactory as none of the specimens reached bond strength values above 110 N, which is the minimum bond strength required according to the standard.

Bond strength of teeth with different types of denture base materials

High impact heat cure resins have shown significantly higher bond strength compared to heat cure resins, irrespective of chemical surface treatments. There was no bonding of teeth with flexible denture base material irrespective of the chemical surface treatment.

For all specimens, interface where failure occurred, were inspected. The failure was classified as adhesive or cohesive in nature. An adhesive failure occurred if there was no trace of denture base resin on the tooth surface or vice versa after fracture. Alternatively, cohesive failure occurred if there was any trace of denture base resin present on the surface of the acrylic tooth or remnants of the acrylic tooth present on the denture base.[6]

One of the most common types of failure in a denture is adhesive type of bond failure between the acrylic resin polymer tooth and the denture base. The benefit of Ethylacetate in improving the bond between acrylic teeth and denture base resins is evident from the results of this study as teeth treated with this chemical failed predominantly in the cohesive mode. Although percentage of cohesive failure in case of monomer, chloroform, acetone was less compared to ethyl acetate, it could be construed as an evidence that the chemicals had facilitated the diffusion of polymerizable materials from the denture base and improved the formation of a more extensive interwoven polymer network. Whereas, degradation products formed at the interface lead to 100% adhesive failure in case of cyanoacrylate adhesive.

Clinical implication of this study is that a simple and quick acrylic tooth chemical surface treatment with ethyl acetate could be an effective option in decreasing bonding failures and also avoid repeated denture repairs, thereby improving patient satisfaction.

After processing, specimens were tested for bond strength using a universal testing machine. The resulting bond strengths were recorded, statistically analyzed and compared.

Results revealed that:

1. Among all the 3types of denture base resins, high-impact heat-cure denture base resin gave higher bond strength. There was no bonding of unmodified teeth with flexible denture base material.
2. **Effect of chemical surface treatments on unmodified teeth:**
   a) Chemical surface treatment of cross-linked acrylic teeth with ethyl acetate gave highest bond strength.
   b) Chemical surface treatment of cross-linked acrylic teeth with monomer gave better bond strength than control group, but less than ethylacetate.
   c) surface treatment of cross-linked acrylic teeth with chloroform and acetone gave better bond strength than control group, but less than monomer.

d) Chemical surface treatment of cross-linked acrylic teeth with cyanoacrylate gave least bond strength, even less than the control group.

Clinical implication of this study is that a simple and quick tooth chemical surface treatment with ethylacetate could be an effective option in decreasing bonding failures and also avoid repeated denture repairs improving patient satisfaction.

Conclusion

Within the limitations of this study following conclusions can be drawn:

1. Among all the 3types of denture base resins, high-impact heat-cure denture base resin gave higher bond strength. There was no bonding of unmodified teeth with flexible denture base material.
2. Effect of chemical surface treatments on unmodified teeth:
   a) Chemical surface treatment of cross-linked acrylic teeth with ethyl acetate gave highest bond strength.
   b) Chemical surface treatment of cross-linked acrylic teeth with monomer gave better bond strength than control group, but less than ethylacetate.
   c) Chemical surface treatment of cross-linked acrylic teeth with chloroform and acetone gave better bond strength than control group, but less than monomer.
   d) Chemical surface treatment of cross-linked acrylic teeth with cyanoacrylate gave least bond strength, even less than the control group.

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