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ORIGINAL ARTICLE

A Study on Effect of Surface Treatments on the Shear Bond Strength between Composite Resin and Acrylic Resin Denture Teeth

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Abstract Visible light-cured composite resins have become popular in prosthetic dentistry for the replacement of fractured/debonded denture teeth, making composite denture teeth on partial denture metal frameworks, esthetic modification of denture teeth to harmonize with the characteristics of adjacent natural teeth, remodelling of worn occlusal surfaces of posterior denture teeth etc. However, the researches published on the bond strength between VLC composite resins and acrylic resin denture teeth is very limited. The purpose of this study is to investigate the effect of five different methods of surface treatments on acrylic resin teeth on the shear bond strength between light activated composite resin and acrylic resin denture teeth. Ninety cylindrical sticks of acrylic resin with denture teeth mounted atop were prepared. Various treatments were done upon the acrylic resin teeth surfaces. The samples were divided into six groups, containing 15 samples each. Over all the treated and untreated surfaces of all groups, light-cured composite resin was applied. The shear strengths were measured in a Universal Testing Machine using a knife-edge shear test. Data were analyzed using one way analysis of variance (ANOVA) and mean values were compared by the F test. Application of bonding agent with prior treatment of methyl methacrylate on the acrylic resin denture teeth resulted in maximum bond strength with composite resin.

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Introduction

Visible light cure composite have become popular for many prosthodontic applications because their wear properties have been improved, especially with newer generation materials. Using visible light-cured (VLC) composite resins for in office replacement of fractured/debonded denture teeth eliminates the need for alternative time-consuming procedures. Visible light-cured composite resins have become popular not only for the replacement of fractured/debonded denture teeth, but also for other prosthodontic applications, such as making composite denture teeth on partial denture metal frameworks, esthetic modification of denture teeth to harmonize with the characteristics of adjacent natural teeth, remodelling of worn occlusal surfaces of posterior denture teeth [1].

The success of these procedures also depend on the adhesion of composite resin to acrylic resin. Review of literature shows limited studies on bond strength between light-cured composite resins and acrylic resin. There are even fewer references in Indian Journals.

This study is aimed to analyze the effect of various surface treatments on the shear bond strength between composite resin and acrylic denture teeth.

Methods

To prepare each sample, initially acrylic molar tooth (Presto-Saver XL-NID products) was trimmed circumferentially to conform to the circumference of Green-stick wax (MAARC GREEN Tracing Sticks). Green-stick wax was then softened at one of its tip and acrylic tooth was embedded to that tip. Sticks of green compound were used as a mold pattern because of their uniform diameter and because their thermoplastic properties allowed them to be flasked and later boiled out in the same manner as a denture wax-up [2]. Optimum amount of dental plaster (Universal's Dental Plaster) was then mixed with water and poured into a flask. Green-stick with attached tooth was invested horizontally in the dental plaster. 5–6 such samples were placed in each flask (Fig. 1). After the plaster had set the flask was placed in boiling water for 10 min for de-waxing. Following wax elimination the tooth remained embedded in plaster adjacent to the mould space (Fig. 2). Liquid and powder of heat-cured acrylic (DPI Heat cure) were then mixed according to the manufacturer's instructions and

Fig. 1 Flasking of Green-stick wax along with acrylic teeth

Fig. 2 Mold space with denture teeth after dewaxing

Fig. 3 Packing of heat-cure acrylic resin into the mold space

packed into the mould space in dough stage (Fig. 3). After curing, cylindrical stick of acrylic resin with denture tooth attached on top was de-flasked [2]. The attached denture tooth was then milled to a diameter of 8 mm to standardize the bond surface area [3]. The occlusal surface of the denture tooth was ground with burs first and then with silicon carbide papers.

Ninety such samples were prepared. Following this, various treatments were done upon the acrylic resin teeth surfaces. The samples were divided into six groups, containing 15 samples each.

Group 1

The acrylic teeth surfaces remained untreated (Control).

Group 2

Teeth surfaces were treated with cold-cured acrylic monomer (DPI-RR cold cure) for 3 min [4].

Group 3

In this group acrylic resin denture teeth surfaces were silanised for 3 min with silanising agent (Silano-Angelus) (to evaluate whether silane has any potential to strengthen the bond between acrylic resin denture teeth and composite as it has upon porcelain and resin composite).

Group 4

The resin teeth surfaces were treated first with silanising agent for 3 min and then with bonding agent (Adper Single Bond-3M ESPE) followed by curing of bonding agent for 40 s.

Fig. 4 Light curing of composite resin placed on surface treated denture teeth

Group 5

Mechanical locks were created with micro-motor hand-piece and burs. 2 × 2 sq.mm locks were created with inverted cone-shaped bur [5].

Group 6

In the last group, surfaces were treated with monomer first for 3 min and then with bonding agent for composite resin and cured for 40 s [4].

Over all the treated and untreated surfaces of all groups, light-cured composite resin (Filtek-3M ESPE) was applied. Light was applied for 40 s (Fig. 4). No more than 1.5 mm layer of composite resin was cured at a time. The thickness of the composite resin was 5 mm over the resin tooth surfaces.

All the specimens were kept in distilled water at room temperature for 7 days before testing.

The shear strengths were measured in a Universal Testing Machine (Instron) using a knife-edge shear test. All specimens were tested on the same day with the same apparatus at ambient temperature. Specimens were wiped dry before they were mounted on the testing apparatus. The samples were secured in a horizontal position with the assistance of a custom aligned metal device and subjected to load until fracture. The specimens were held in the fixture in such a manner that the cross head applied a force parallel to the acrylic resin denture tooth and composite resin interface (Fig. 5). A metal blade with an edge thickness of 0.8 mm was moved vertically at a cross-head speed of 0.5 mm/min to break the surfaces at the tooth-composite interface (Fig. 6). The maximum load (N), at break, for each specimen was divided by the bonding area (mm^2), to express the bond strength (MPa).

i.e. Shear bond strength 'σ' (MPa) $= L/A$, where L is the load (N) for rupture of the specimen and A is the interfacial area (mm^2) as measured with a digital caliper before testing.

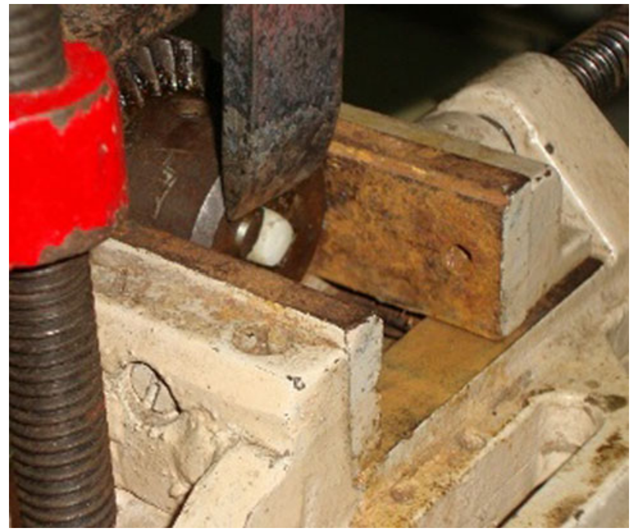


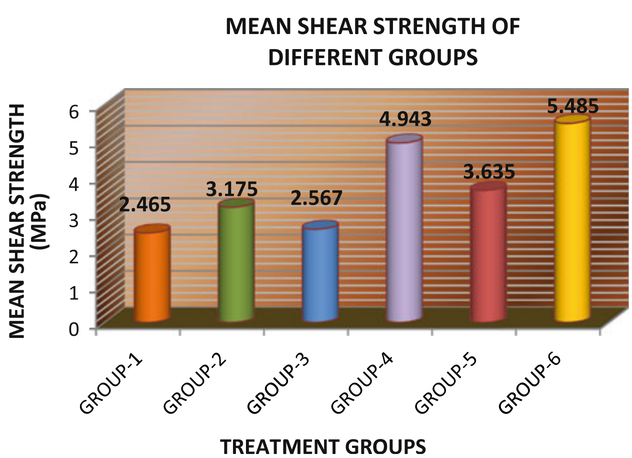
Fig. 5 Sample placed in the custom aligned metal device

Results and Analysis

Table 1 depicts the values of the shear bond strength in the six different treatment groups.

Data were subjected to statistical analysis. Calculated Mean and Standard deviation of the original values are shown in Table 2.

The comparison between the mean shear strengths of the six groups is displayed with the help of a Bar-Diagram:-



For testing significance of the differences in the mean values One-way Analysis of Variance (ANOVA), using F test statistic of the data, were carried out as shown in Table 3.

Now, Variance Ratio 'F' value being highly significant ($p < 0.001$) we can say that there exists significant differences between the treatment averages. Then the Critical Difference (C.D.) values were calculated and used to compare the different treatment means as shown in Table 4.

Fig. 6 Fractured sample

Table 1 Bond strengths (MPa) of individual samples

Sample No.	Group-1	Group-2	Group-3	Group-4	Group-5	Group-6
1	2.378	2.991	2.051	2.200	1.013	1.846
2	2.286	2.130	1.963	5.390	3.779	4.876
3	1.986	4.264	2.825	5.420	3.923	3.544
4	2.582	2.702	3.146	4.744	3.383	5.734
5	2.652	3.229	3.121	5.083	3.652	5.201
6	2.172	2.643	2.452	5.207	4.022	7.657
7	2.872	3.654	2.153	5.480	3.287	5.839
8	2.400	3.488	2.359	4.772	3.755	6.466
9	2.000	2.394	2.009	4.639	4.252	6.431
10	2.425	2.819	3.017	5.739	3.353	3.836
11	2.145	3.388	2.545	4.938	3.951	6.680
12	2.783	4.763	2.685	5.249	4.052	6.150
13	2.249	3.078	2.171	4.423	4.288	5.064
14	2.964	3.492	2.902	5.629	3.838	6.015
15	3.077	2.586	3.102	5.228	3.984	6.934

Thus, from the above analysis it can be summarized that:-

A. All bond strength mean values are significantly greater than that of Control (Group-1)
B. There is no significant difference between the mean values of Group-2 and Group-3, Group-2 and Group-5 and between Group-4 and Group-6.
C. All other comparison of mean values are significant.

Discussion

Using visible light-cured (VLC) composite resins for in office replacement of fractured/debonded denture teeth eliminates the need for time-consuming procedures. To achieve optimum bond strength between composite resin and acrylic resin, it is essential that a good bond exists between these two materials.

Table 2 Mean & SD of the six groups

Treatment groups	Mean	SD
Group-1	2.465	0.345
Group-2	3.175	0.703
Group-3	2.567	0.435
Group-4	4.943	0.847
Group-5	3.635	0.786
Group-6	5.485	1.497

Table 3 Analysis of Variance (ANOVA)

Source	Degree of freedom	Sum of squares	Mean sum of squares	'*F*'
Between treatment groups	5	117.2937	23.4587	32.15 ($p < 0.001$)
Within treatment groups	84	61.2872	0.7296	
Total	89	178.5809		

Denture teeth are mainly composed of Polymethyl methacrylate (PMMA) and Polyethyl methacrylate (PEMA). Because of the manufacturing process (heat curing or cross-linking), the degree of conversion is relatively high in these materials [6].

It has been suggested that wetting heat polymerized acrylic resin surfaces with methyl methacrylate (MMA) for 180 s dissolves the surface structure of polymethyl methacrylate (PMMA), increasing the bond strength of repaired heat polymerized resin [4]**.** This provides free double bonds that can copolymerize with the composite material. The polymerization process of MMA and composite resin matrix (BISGMA) follow a similar pattern of activation and cross-linking, because the reactive methacrylate groups of the molecules are similar. Some chemical bonding between composite and acrylic resin thus occur, if cross-links are provided on the acrylic resin teeth for bonding to the composite. However, it is also possible that there is no occurrence of chemical bonding. MMA may also swell the denture tooth, allowing the composite to penetrate into surface micro irregularities and yield a mechanical bond. In reality, there is probably a combination of chemical and mechanical bonding between the composite and the MMA-treated acrylic denture tooth [7].

However, in our study, the mean bond strength of Group-2 (MMA-treated) is greater than Group-1 (control) and Group-3 (Silane-treated) but lesser than the other groups. The results indicate that the use of MMA to soften the acrylic resin denture teeth did not provide sufficient active sites to react with composite resin. The poor

Table 4 Comparison of treatment means

Treatment groups	Group-2		Group-3		Group-4		Group-5		Group-6	
	'*d*'	'*p*'	'*d*'	'*p*'	'*d*'	'*p*'	'*d*'	'*p*'	'*d*'	'*p*'
Group-1	0.71	<0.05	0.102	<0.01	2.478	<0.001	1.170	<0.001	3.02	<0.001
Group-2			−0.608	NS	1.768	<0.001	0.46	NS	2.31	<0.001
Group-3					2.376	<0.001	1.068	<0.001	2.918	<0.001
Group-4							−1.308	<0.001	0.542	NS
Group-5									1.85	<0.001
Group-6										

'*d*' stands for difference in the treatment means

'*p*' denote the level of significance of the difference of the treatment means (*d*)

'NS' stands for non-significant ($p > 0.05$) difference between the treatment means

wettability property of the high viscosity composite material probably influenced the result in this group.

Another material 'Silane' plays a significant role in adhesion processes. Silane reaction mechanisms are not entirely understood and there exist several theories of bonding mechanisms between silanes and substrates. However, silanes are continuously used to bond metal, ceramic and composite to each other. Surface silanized composite materials showed improved shear bond strength in comparison with non-silanized ones [8]. But, in contrast, bonding between acrylic and composite resin is not much influenced by silanization as measured in our study. Group-3 (Silane-treated) had the lowest mean bond strength in this study being greater only to Group-1 (control).Thus, overall conclusion might be difficult to make giving way to continuous discussion as to whether silanization is needed or not.

Bonding agent (i.e. unfilled resin) has long been used with composite resin in restorative dentistry. It improves the surface wetting by causing infiltration of the resin into microscopic surface irregularities. Andres Guzman and B. Keith Moore [9] showed that a bonding agent was essential for the achievement of an adequate bond strength between the light-activated and heat-polymerised resin. In their study regarding bond strength between composite resin and acrylic resin denture teeth Vergani et al. [4], suggested that the use of adhesive produced greater bond than use of MMA only.

In our study, in Group-4, samples were treated with Silane and Bonding agent. The mean value obtained was greater than all the other groups, except Group-6, in which the samples were treated with MMA followed by Bonding agent. But the difference between Group-4 and Group-6 was not statistically significant ($p > 0.05$). This suggests that the high mean bond strengths of these two groups results from use of the bonding agent. The combined surface treatment of MMA with application of light-cured bonding agent in Group-6, provided the highest shear bond strength which was statistically significantly greater than Group-1, 2, 3 and 5 ($p < 0.001$). Since the surfaces in this group were primed with MMA, the adhesive-monomer combination appears to promote better bonding. This bond is formed by the diffusion and polymerization of MMA across the acrylic tooth-composite resin interface to form interpenetrating polymer networks. But in case of Silane this mechanism is not predictable resulting in the relatively lower mean bond strength achieved in Group-4 with respect to Group-6. In both, Group-4 and 6, surface treatment using a bonding agent proved to be an excellent bond promoter agreeing with the findings of other investigators' results [6].

Mechanical locks were used in Group-5 for adhesion. The mean bond strength was greater than Group-1, 2 and 3 but lesser than Group-4 and 6. But statistically the difference between Group-2 (MMA treated) and Group-5 (mechanical locks) was not significant ($p > 0.05$). So retention due to mechanical locks provided an intermediate bond strength.

Thus, the result of the present in vitro study points towards the superiority of bonding agent in promoting adhesion between acrylic resin denture tooth and composite resin. However, it must be noted that in vitro studies are limited in predicting the success of a material or technique in clinical use because the factors responsible for bond degradation in the oral environment cannot be simulated exactly in the experimental conditions. The use of a simple cylindrical shaped specimen rather than a complex denture design, as well as the absence of longer periods of water storage or thermocycling, are limitations of the present study and should be investigated in the future. But, though the experimental method does not imitate the intraoral situation, it does provide an effective mean of comparing the influence of five different type of surface treatments, on the shear bond strength between acrylic resin denture tooth and composite resin under controlled conditions [10].

Within the parameters and conditions of this study the following conclusions can be drawn:-

1. Application of bonding agent with prior treatment of methyl methacrylate on the acrylic resin denture teeth resulted in maximum bond strength with composite resin.
2. Silane solely had little effect on the bond strength between acrylic teeth and composite resin but when applied with bonding agent the bond strength was quite high.
3. Mechanical lock had moderate influence on the bond strength producing results significantly greater than untreated and silane treated samples.
4. The use of methyl methacrylate alone had the same outcome as mechanical locks and the difference between these two groups were not significant.

Acknowledgment School of Bioscience and Engineering, Jadavpur University, Kolkata.

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