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"Effect of various surface treatments on the bond strength of crosslinked acrylic resin denture teeth with high impact resistant heat-polymerized acrylic resin"-an in-vitro study.

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Abstract:
Background and Objectives: *The debonding of acrylic teeth from denture base remains a major problem in removable prosthodontic practice. Recent advances had led to the introduction of highly crosslinked acrylic teeth and reinforced acrylic denture base resin with better properties. But this had also affected the chemical bond between them. Hence all possible methods to improve the bond strength should be studied. The main objective of the present study were to evaluate the bond strength between high impact resistant heat polymerized denture base resin and crosslinked acrylic denture teeth after sandblasting and after different chemical surface treatments with methyl methacrylate monomer, acetone, chloroform, and ethyl acetate.*
Material and Methods:*Master specimen was prepared by making a wax block, of size 8mmX10mmX20mm, with a 45^0 taper on the long side to which the ridge lap surface of the maxillary central incisors was bonded. A metal die was fabricated and a mold was made. A total of 60 specimens were fabricated and divided into six groups with 10 specimens each according to the surface treatment on ridge lap area of acrylic teeth. After processing, specimens were tested for bond strength using a universal testing machine. The resulting bond strength was recorded and was statistically analyzed.*
Results: *Among all six groups surface treatment of acrylic teeth with sandblasting along with ethyl acetate application showed the highest bond strength.*
Interpretation and Conclusion: *Sand blasting along with ethyl acetate application is a better surface treatment option to be used to improve the bond strength of crosslinked acrylic denture teeth to high impact resistant heat polymerized acrylic resin.*
Key Words: *Bond strength; Acrylic tooth; Surface treatment*

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I. Introduction

Natural tooth loss is a matter of great concern to majority of the people and their replacement with artificial substitute such as dentures, fixed prosthesis or implants is vital to continuance of oral health. Any damage to this artificial prosthesis will lead to immense psychological stress for the patients.Acrylic resin is an indispensable material in the removable prosthodontics. Unfortunately, removable restorations that are made totally or partially with acrylic resin tend to fracture if dropped or stressed beyond their fracture strength. Recently, to prevent fracture of denture bases, acrylic resin with greater mechanical properties by reinforcing the PMMA with other materials like fibers or Metals, were introduced.

Adequate bonding of acrylic resin teeth to the denture base resin is necessary because it increases stiffness and strength of the prosthesis. Recent advances lead to the introduction of highly cross-linked acrylic teeth with better fracture resistance, abrasion resistance and stain resistance. But on the other hand its bonding ability to the denture base was found to be reduced.It has been estimated that between 22% and 33% of denture repairs involve tooth debonding of anterior teeth may be attributed to a lesser ridge lap surface available for bonding and the direction of stresses encountered during function.[1]Given that one of the advantage of acrylic resin teeth is the ability to chemically bond to denture base resins, one probable explanation for this type of failure would be the presence of impurities on the tooth surface. Impurities could include residual wax because of incomplete elimination or contamination of the ridge-lap surfaces with tinfoil substitute. Such materials can prevent chemical bonding between acrylic teeth and denture base resins.

In literature, several methods have been suggested by various authors to improve the bond strength between acrylic resin teeth and denture base resins. These include placement of retentive grooves on the ridge-lap area of the teeth, application of chemical agent on the ridge-lap areas and sandblasting the ridge-lap area. All these methods have been individually tested and compared keeping untreated teeth as control group. In all these

studies, a definitive increase in bond strength has been reported by employing one of these methods of enhancing retention. These methods of improving the bond strength between acrylic resin teeth and denture base resin have been separately studied but very few studies have evaluated and compared all these methods together along with an untreated surface. Hence the present study was undertaken to evaluate and compare the effect of combined chemical and mechanical treatment of the ridge-lap surface of acrylic teeth on bond strength of acrylic resin teeth to denture base resin.

II. Materials And Methodology

Instruments and materials used during the course of this study:

Instruments:

1. Dental Flask and Clamps.
2. Measuring cup.
3. Porcelain jars with lid.
4. Mixing spatula.
5. Sand paper (P320 grit).

Materials:

1. High impact resistant Heat-polymerized Acrylic resin (Trevalon HI).
2. Cross linked Acrylic denture teeth (Acry rock).
3. Modelling wax (Hindustan)
4. Paint brush.
5. Dental stone (Kalabhai)
6. Dental plaster (Kalabhai)
7. White Petroleum jelly (Bioline)
8. Silicone impression material (photosil, DPI)
9. Methyl methacrylate monomer (Heatcure monomer)
10. acetone
11. chloroform
12. ethyl acetate

Equipment's:

1. Hydraulic bench press. (OMEC, ITALY TYPE P1 8500)
2. Universal testing machine. (FIE, UTE Series 9302)
3. Acrylizer. (UNIDENT)
4. Sand blasting unit. (CONFIDENT.SANTER Labo16 model C-128)
5. Profile projector (METZER, METZ-801)

Source of the data:

This study was conducted at the Department of Prosthodontics including crown & bridge and Implantology, K.V.G Dental College and Hospital, Sullia, K.V.G Engineering College, Sullia and Cauvery Polytechnic College, Gonikoppal.

Preparation of the specimens:

Test specimens were prepared simulating clinical condition, as described in Japanese Standard on Acrylic Resin Teeth JIST 6506 (1989).[2] Master specimen was prepared by making a wax block, of size 8mmX10mmX20mm, with a 45^0 taper on the long side to which the ridge lap surface of the selected acrylic teeth was bonded. In order to standardize the tooth, only the maxillary central incisors of the same brand and mold were used. A metal die was fabricated using the master specimen. A mold was fabricated by taking the impression of the metal die using silicone impression material. The selected teeth 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 and specimens with any change in angulation were discarded.

A total of 60 specimens were divided into six groups which differ on the basis of surface treatment on ridge lap area of cross linked acrylic teeth.

Groups were as follows-

Group A- The ridge lap area of cross linked acrylic tooth was left untouched and untreated; this was used as the control group.

Group B- The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification.

Group C -The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with methyl methacrylate monomer.

Group D- The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with acetone.

Group E- The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with chloroform.

Group F- The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with ethyl acetate.

Method of Data collection:

The test specimens comprises wax blocks, of size 8mmX10mmX20mm, with a 45^0 taper on the long side to which the ridge lap surface of the maxillary central incisor teeth was bonded .

- Flasking and dewaxing of wax blocks was done following standard technique.
- After careful dewaxing the ridge lap area of 10 cross linked acrylic teeth was left untouched and untreated, this was used as the control group.
- The ridge lap area of 10 cross linked acrylic tooth was subjected to sand blasting with aluminum oxide of 50 -100 microns as surface modification.
- The ridge lap area of 10 cross linked acrylic tooth was subjected to sand blasting with aluminum oxide of 50 -100 microns as surface modification and methyl methacrylate monomer was applied with paint brush 3 times and left to dry for 10 minutes.
- The ridge lap area of 10 cross linked acrylic tooth was subjected to sand blasting with aluminum oxide of 50 -100 microns as surface modification and acetone was applied with paint brush 3 times and left it for 10 minutes.
- The ridge lap area of 10 cross linked acrylic tooth was subjected to sand blasting with aluminum oxide of 50 -100 microns as surface modification and chloroform was applied with paint brush 3 times and left it for 10 minutes.
- The ridge lap area of 10 cross linked acrylic tooth was subjected to sand blasting with aluminum oxide of 50 -100 microns as surface modification and ethyl acetate was applied with paint brush 3 times and left it for 10 minutes.
- After surface treatment, heat-polymerized acrylic resin was packed into the mold space following manufacturer's instructions and processed by conventional technique.
- The flask was closed once again and kept under hydraulic bench press at 1000 psi for 15 minutes.
- Specimens were bench cooled overnight for 10 hours at room temperature.
- Deflasking was done carefully and the acrylic blocks were carefully retrieved.
- The acrylic blocks were finished with sand paper and then it was polished with polishing cake.

Testing the specimen

The prepared specimens were subjected to shear load testing using a universal testing machine. The test specimens were placed in the lower jaw of the universal testing machine and a vertical rod mounted on the upper jaw of the universal testing machine was aligned to apply load on the palatal aspect of the denture teeth at an angle of 130 degree to the long axis of teeth. A crosshead speed of 0.5 mm min^{-1} was used for testing the bond strength. Load was applied until the denture teeth get separated from the denture base resin. The correct bond strength values were recorded and were statistically analyzed.

III. Result

The purpose of this study is to compare bond strengths of denture teeth to high impact resistant heat polymerized acrylic resin after mechanical and chemical surface treatments.

Six experimental groups were made on basis of surface treatment of ridge lap area of cross linked acrylic teeth for this study.

Groups are as following-

Group A - The ridge lap area of cross linked acrylic tooth was left untouched and untreated, this was used as control group.

Group B - The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification.

Group C -The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with methyl methacrylate monomer
Group D - The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with acetone.
Group E - The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with chloroform.
Group F - The ridge lap area of cross linked acrylic tooth was subjected to sand blasting as surface modification and chemically treated with ethyl acetate.

Data was analysed using one way ANOVA and The Tukey HSD Post Hoc test to find the significance between the groups. Ms- excel 2010 was used to compute the descriptive statistics and statistical package for social sciences (SPSS 16) was used to analyse the data.

P values (probability) range in four classes
$P > 0.05$ - Not significant
$P < 0.05$ – Significant
$P < 0.01$ – Highly significant
$P > 0.001$ - Very highly significant

Table interpretation

The table shows the bond strength of crosslinked acrylic resin tooth to high impact denture base resin after various mechanical and chemical treatments on the ridge lap surface of teeth. The control group had mean bond strength of 144 N. The highest bond strength was noted for Group F with mean bond strength of 173 N followed by Group E with a mean of 167 N. The lowest strength was recorded for Group A

Table1. The table shows the bond strength of crosslinked acrylic resin tooth to high impact denture base resin after various mechanical and chemical treatments on the ridge lap surface of teeth.

GROUPS / SAMPLES	GROUP A	GROUP B	GROUP C	GROUP D	GROUP E	GROUP F
1	150	160	160	150	180	190
2	130	140	170	160	150	180
3	140	170	150	140	170	150
4	130	140	140	160	190	160
5	160	140	150	160	150	170
6	160	170	170	170	190	160
7	150	160	150	160	160	180
8	130	160	140	180	180	160
9	150	140	170	170	150	200
10	140	160	160	160	150	180
AVERAGE	**144**	**154**	**156**	**161**	**167**	**173**

values in Newton's

Table2. The table shows mean load of six study groups for bond strength along with standard deviation, standard error, lower bound and upper bound at 95% Confidence Interval for Mean and with minimum and maximum values.

GROUPS	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
GROUP A (CONTROL)	10	144	11.73788	3.71184	135.6032	152.3968	130.00	160.00
GROUP B	10	154	12.64911	4.00000	144.9514	163.0486	140.00	170.00

GROUP C	10	156	11.73788	3.71184	147.6032	164.3968	140.00	170.00
GROUP D	10	161	11.00505	3.48010	153.1275	168.8725	140.00	180.00
GROUP E	10	167	17.02939	5.38516	154.8179	179.1821	150.00	190.00
GROUP F	10	173	15.67021	4.95536	161.7902	184.2098	150.00	200.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5228.333	5	1045.667	5.744	.000
Within Groups	9830.000	54	182.037		
Total	15058.333	59			

Table3. The table shows the result of one way ANOVA test,

The table shows the result of one way ANOVA test. The p-value for interaction is calculated as 0.000 which is statistically highly significant.

Table4. The table shows the probabilities for Post Hoc test using Tukey HSD test

Multiple Comparisons

value
Tukey HSD

					95% Confidence Interval	
(I) group	**(J) group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
GROUP A (CONTROL)	GROUP B	-10.00000	6.03386	>0.05	-27.8269	7.8269
	GROUP C	-12.00000	6.03386	>0.05	-29.8269	5.8269
	GROUP D	-17.00000	6.03386	>0.05	-34.8269	.8269
	GROUP E	-23.00000*	6.03386	<0.05	-40.8269	-5.1731
	GROUP F	-29.00000*	6.03386	<0.05	-46.8269	-11.1731
GROUP B	GROUP A (CONTROL)	10.00000	6.03386	>0.05	-7.8269	27.8269
	GROUP C	-2.00000	6.03386	>0.05	-19.8269	15.8269
	GROUP D	-7.00000	6.03386	>0.05	-24.8269	10.8269
	GROUP E	-13.00000	6.03386	>0.05	-30.8269	4.8269
	GROUP F	-19.00000*	6.03386	<0.05	-36.8269	-1.1731
GROUP C	GROUP A (CONTROL)	12.00000	6.03386	>0.05	-5.8269	29.8269
	GROUP B	2.00000	6.03386	>0.05	-15.8269	19.8269
	GROUP D	-5.00000	6.03386	>0.05	-22.8269	12.8269
	GROUP E	-11.00000	6.03386	>0.05	-28.8269	6.8269
	GROUP F	-17.00000	6.03386	>0.05	-34.8269	.8269
GROUP D	GROUP A (CONTROL)	17.00000	6.03386	>0.05	-.8269	34.8269
	GROUP B	7.00000	6.03386	>0.05	-10.8269	24.8269
	GROUP C	5.00000	6.03386	>0.05	-12.8269	22.8269
	GROUP E	-6.00000	6.03386	>0.05	-23.8269	11.8269
	GROUP F	-12.00000	6.03386	>0.05	-29.8269	5.8269
GROUP E	GROUP A (CONTROL)	23.00000*	6.03386	<0.05	5.1731	40.8269

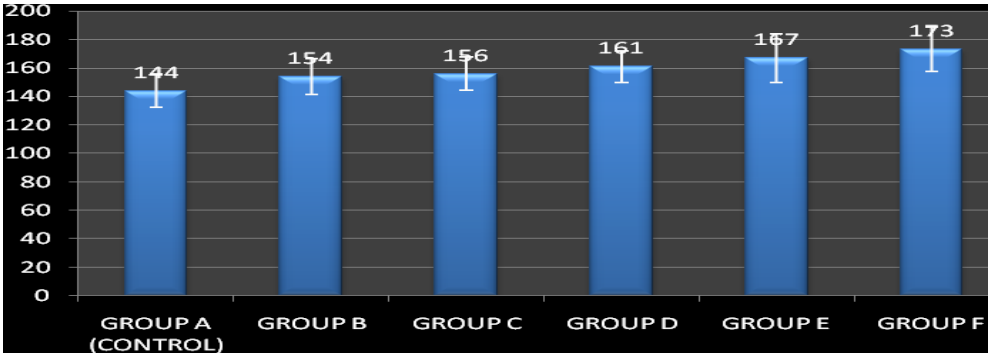
	GROUP B	13.00000	6.03386	>0.05	-4.8269	30.8269
	GROUP C	11.00000	6.03386	>0.05	-6.8269	28.8269
	GROUP D	6.00000	6.03386	>0.05	-11.8269	23.8269
	GROUP F	-6.00000	6.03386	>0.05	-23.8269	11.8269
GROUP F	GROUP A (CONTROL)	29.00000*	6.03386	<0.05	11.1731	46.8269
	GROUP B	19.00000*	6.03386	<0.05	1.1731	36.8269
	GROUP C	17.00000	6.03386	>0.05	-.8269	34.8269
	GROUP D	12.00000	6.03386	>0.05	-5.8269	29.8269
	GROUP E	6.00000	6.03386	>0.05	-11.8269	23.8269

*. The mean difference is significant at the 0.05 level

This table shows the probabilities for Post Hoc test using Tukey HSD test. The table shows statistically highly significant differences in the bond strength of the following groups.

(a) Group A with groups E and F.
(b) Group B with group F.
(c) Group E with Group A.
(d) Group F with Groups A and B.

Graph interpretation



Graph 1: Comparison of mean bond strength between all six groups with standard error.

IV. Discussion

The debonding of acrylic resin teeth from denture base resin remains a major problem in removable prosthodontic practice. For an effective bond to happen the polymerizing denture base resin must come into good physical contact with the denture teeth resin and the polymer network of the denture base resin must react chemically with the denture tooth resin polymer to form an interwoven polymer network. Several mechanical and chemical modifications on the ridge lap area of acrylic resin teeth were employed to enhance the bonding of acrylic resin teeth to denture base resin.

Bond failure could either be adhesive failure or cohesive failure. Adhesive failure occurs if there is no trace of any denture base resin on the tooth surface after the fracture, cohesive failure occurs if there is presence of any traces of denture base resin on the surface of denture teeth or remnants of the denture tooth on the denture base. The denture tooth often separates from the denture base without any damage to the denture base or teeth indicating predominant adhesive failure.

Recent advances had led to the introduction of highly crosslinked acrylic teeth with better fracture resistance, abrasion resistance and stain resistance but also resulted in a decreased chemical bond as compared to acrylic resin teeth without crosslinking. Clancey reported that heat cured plastic teeth were 40% higher in bond strength than with IPN crosslinked teeth.[3] And by the introduction of reinforced acrylic denture base resins with better mechanical properties had further affected the bonding properties of crosslinked acrylic tooth to high impact denture base resins. Marrow et al found that the bond strength of high impact resin to plastic teeth was not significantly greater than that of standard resin, although the tensile strength of high impact resin was significantly greater than that of standardized resin.[4] With implant retained prosthesis, both the improved wear characteristics and strength characteristics of a highly crosslinked denture tooth and the use of high impact resistant denture base are important. Hence all possible methods to improve the bond strength of crosslinked acrylic tooth with high impact resistant heat polymerized acrylic resin should be studied.

The present study was conducted to compare bond strengths of crosslinked denture teeth to high impact resistant heat polymerized acrylic resin after mechanical and chemical surface treatments. Out of the various methods of preparing specimens and testing bond strength, designed to comply with various national standards. The method of Japanese standard for acrylic resin teeth (JIS T 6506, 1989) was used for preparing the test specimen. The bond strength was tested by applying shear compressive force on the lingual surface of the teeth at an angle of 130 degrees to the long axis of the teeth. According to Cardash et al (1990) Applying shear compressive force on the lingual surface of the teeth at an angle of 130 degrees to the long axis of the teeth stimulates the forces applied to maxillary denture teeth in clinical situation. And this angle was chosen to stimulate the average angle of contact found in a class 1 occlusion between maxillary and mandibular anterior teeth.[5]

The mean bond strength of each specimen was calculated in newton's (N). The control group were the ridge lap area of acrylic tooth was left untouched and untreated showed mean bond strength of 144. Comparing the control group all other groups had shown increase in bond strength and the highest bond strength was noted for Group F were the ridge lap area of acrylic tooth was subjected to sandblasting and chemically treated with ethyl acetate. Chung et al revealed that sandblasting the ridge lap area with 50µ could only remove the glaze on the ridge lap area but had no significant effect in improving the bond strength between the denture base resin and acrylic resin teeth.[6] In this present study, sandblasting the ridge lap area with aluminium oxide had increased the bond strength when compared with the control group but the values were not statistically significant.

Though the application of heat cure monomer over the sand blasted ridge lap surface had increased the bond strength when compared to the control group, the difference in mean bond strength between the Group B (Sandblasting of ridge lap area) and Group C (sandblasting + monomer application) was very less. This shows that the application of monomer doesn't had much effect on increasing the bond strength of already sandblasted ridge lap surface. This may be because monomer is not a powerful solvent for polymethyl methacrylate (PMMA), painting the surface might not have efficiently removed the debris to produce a particle free surface for bonding. This can be also related to the long period (10minutes) between application of monomer and packing. According to Vallittu P K in 1997 when a solvent comes in contact with a polymer, the surface of the polymer swells because of diffusion of the solvent into the polymer. This diffusion is dependent on time, temperature, type of solvent and the polymeric structure and glass transition temperature of the polymer.[7]

Similar to application of monomer, application of acetone on sand blasted ridge lap surface of acrylic tooth also showed an increase in mean bond strength which was not statistically significant. Stoia A E, Tudor A studied the dynamic of acetone effects induced to the superficial layer of acrylic teeth, two different effects: one regarding the softening and swelling of the superficial layer and other regarding the hardening of superficial layer was noticed.[8] The hardening of superficial layer was given as a reason for lower tensile strength values of acetone treated sample group compared to control group after tensile strength testing. In the present study longer period (10 minutes) between application of acetone and packing might have led to the hardening of superficial layer of acrylic resin tooth which resulted in less significant increase in shear bond strength values. Sinasi Sarac et al in 2005 applied acetone on the bonding surface for 30 seconds and found that application of acetone created a smoother surface with superficial pit and the bond strength was improved with acetone surface treatment.[9]

Both chloroform and ethyl acetate are non polymerizable solvents with the potential to swell and soften the superficial surface of the acrylic tooth thereby enhancing the diffusion of the polymerizable material resulting in increased strength of interwoven polymer network. In the present study application of both chloroform and ethyl acetate on the sandblasted ridge lap surface showed significant increase in shear bond strength compared to control group. But when compared to Group B (ridge lap surface treated with sandblasting a surface modification) only ethyl acetate showed a significant increase in shear bond strength. This shows that the increase in bond strength after both sandblasting and application of ethyl acetate on ridge lap was significantly more than the bond strength after sandblasting only. Though adhesive failures were predominant; most of the specimens treated with ethyl acetate showed cohesive failure. This shows the benefit of ethyl acetate application in improving the bond strength of crosslinked acrylic tooth and high impact denture base resin.

In this study the effectiveness of both mechanical and chemical modification together on the ridge lap surface was significantly higher than that with only mechanical modification, in case of ethyl acetate. So sandblasting along with application of ethyl acetate on the ridge lap surface of crosslinked acrylic denture teeth before denture processing is an effective option in decreasing bond failures.

Limitation

Even though the study proved to be effective in evaluating the bond strength between crosslinked acrylic denture teeth and high impact resistant heat polymerized acrylic resin it had certain limitations. As the study was conducted in vitro, its method and variables do not represent all clinical conditions. The universal

testing machine used for testing the bond strength gave all the values in multiple of ten. Hence the exact loading force value resulted in bonding failure was unable to record. This study design did not consider the effect of aging, thermocycling and cyclic loading of the test specimens. And also the time period between chemical surface treatment and packing of acrylic resin is a factor that affects bonding which was not considered in this study. Future studies considering all these limitations are recommended for a better result.

Clinical significance

Mechanical modification with sandblasting along with ethyl acetate application on the ridge lap surface of crosslinked acrylic denture teeth is an effective option to reduce bond failures and it also avoids repeated denture repairs, thereby improving patient satisfaction.

V. Conclusion

Within the limitations of this study, the following conclusions were drawn:

1. The mechanical surface modification of ridge lap area of crosslinked acrylic resin teeth by sand blasting had improved the shear bond strength between high impact resistant heat cure denture base resin and acrylic resin teeth but was not statistically significant.
2. The application of chemicals like methyl methacrylate monomer, acetone and chloroform after mechanical modification by sandblasting on the ridge lap surface of crosslinked acrylic resin teeth gave better bond strength than control group.
3. The Chemical surface treatment after sandblasting on the ridge lap surface of crosslinked acrylic resin teeth with ethyl acetate gave highest shear bond strength.
4. Both sand blasting and surface treatment with ethyl acetate together on the ridge lap surface was more effective than that with only mechanical modification using sand blasting.
5. Sand blasting along with ethyl acetate application, with its improved bond strength properties and mostly with the cohesive mode of failure would serve as a better surface treatment option to be used to improve the bond strength of crosslinked acrylic denture teeth to high impact resistant heat polymerized acrylic resin.

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