



AMERICAN JOURNAL OF PHARMTECH RESEARCH

Journal home page: <http://www.ajptr.com/>

In Vitro Evaluation of the effect of Surface Treatment of Artificial Tooth on the Adhesive Bond Strength to Commercially Available Denture Base Resin.

Gurkaran Preet Singh¹, Veena Hegde*², Prerna Jain³

1. Consultant Prosthodontist, Max Super Speciality Hospital, Mohali, Punjab, 160071 India.

2. Professor and Former Head of the Department, Department of Prosthodontics and Crown & Bridge, Manipal College of Dental Sciences, Manipal, Karnataka 576104 India.

3. Senior lecturer, Department of Orthodontics, Gian Sagar Institute of Dental Sciences, Banur, Punjab, 140601 India

ABSTRACT

This prospective interventional in-vitro study was aimed at evaluating the effect of pre-processing treatment of ridge-lap surfaces of acrylic teeth, on the strength of the bond between the teeth and the denture base resin. Three test groups included application of mono-methylmethacrylate, air-abrasion with 110- μ m aluminium oxide particles and combination of the two methods. A total of 40 tooth-acrylic resin samples were equally divided into four groups (three test groups and one control group) and shear load testing was carried out in the Universal testing machine. Tukey post-hoc analysis revealed that Group IV had significantly higher mean compressive strength than Group I (* $p < 0.05$). No significant differences were present in any of the group comparisons. There was a significant effect produced on the shear bond strength of the interface only when both MMA application and air-abrasion of the ridge-lap surfaces was carried out. Fracture analysis revealed that most of the specimens showed cohesive failure at the interface with adhesive failure restricted to control group exclusively. Despite reported progress in the development of denture base resins and artificial tooth materials, the bond between acrylic denture teeth and denture base materials remains unreliable, inconsistent and unpredictable. Adhesive bond strength between denture base resin and artificial teeth constitutes one of the most important considerations in the technical procedure related to the fabrication of removable dentures.

Keywords: Prospective, interventional, in-vitro study, denture base resin, denture tooth, shear bond strength, mono-methylmethacrylate resin, air-abrasion, universal testing machine.

*Corresponding Author Email: drveenahebbbar@yahoo.com

Received 24 April 2018, Accepted 04 May 2018

Please cite this article as: Hegde V *et al.*, In Vitro Evaluation of the effect of Surface Treatment of Artificial Tooth on the Adhesive Bond Strength to Commercially Available Denture Base Resin. American Journal of PharmTech Research 2018.

INTRODUCTION

Majority of commercially available, pre-formed artificial teeth are essentially made of acrylic or vinyl-acrylic resin; which is chemically very similar to acrylic resin, a widely used bio-material [1,2]. Consequently, this inherent ability to chemically bond to the denture base along with higher shock absorbability, ease of adjustment and low cost has led to widespread use of acrylic teeth in removable prosthodontics [3,4].

Despite reported progress in the development of denture base resins and artificial tooth materials, debonding of acrylic teeth from the denture base remains a common clinical occurrence in prosthodontic practice, involving 22% to 30% of denture repairs annually. The incidence of such failure assumes greater proportion in the provision of implant-supported overdentures as a result of significantly higher masticatory forces associated with such prosthesis [3]. The bond between acrylic denture teeth and denture base materials remains unreliable, inconsistent and unpredictable. Nonetheless, adequate bonding of acrylic resin teeth to denture base resin is imperative for the strength and durability of the denture as well, since the teeth become an integral part of the prosthesis [5]. Therefore, adhesive bond strength between denture base resin and artificial teeth constitutes one of the most important considerations in the technical procedure related to the fabrication of removable dentures [6].

Recent literature is replete with studies that have aimed at investigating various factors that may influence the bond strength of the denture tooth-base joint and have stated measures to increase the same.

In recent years, several new materials for denture construction have been introduced such as an inter-penetrating network for denture tooth construction, with claims of increased wear resistance, better aesthetics and more convenient curing methods. Although reports of enhanced tooth properties exist, few studies on the bond between an IPN acrylic tooth and acrylic denture base material have been reported [7].

Also it is believed by many, that current research investigating the surface treatment of metals to improve bonding of polymeric restorative materials may have some applications to tooth–denture bonding procedures. However, there are only few studies on sandblasting of the denture base and limited information is available on the use of sandblasting to increase the bond strength of a denture tooth to denture base [7].

Against this backdrop of scarcity of information, this prospective interventional in-vitro study was aimed at evaluating the effect of pre-processing treatment of ridge-lap surfaces of acrylic teeth, on

the strength of the bond between the teeth and the denture base resin. A secondary objective was to analyse the fractured interface under stereomicroscope and appropriately classify failure mode.

MATERIALS AND METHOD

The current study was initiated after obtaining protocol-approval from the institute review board. In the present study, the effect of three pre-processing surface treatment variables on the shear bond strength of a commercially available cross-linked acrylic tooth to a heat-polymerised denture base resin was investigated. These pre-processing treatment modalities included:

1. No conditioning of the ridge-lap surface of the tooth- control group (Group I).
2. Mechanical modification of ridge-lap surface by air-abrasion with 110- μ m aluminium oxide particles at 4.9 Kgf/cm² air pressure at 1 cm distance for 10 seconds (Group II),
3. Chemical modification by application of methyl-methacrylate monomer 10 minutes before acrylic resin packing and once just before packing of denture base resin (Group III) and lastly
4. Combination of aforementioned modalities with air-abrasion done at the initial stage and MMA conditioning done prior to acrylic resin packing (Group IV).

Specimen Preparation

For purpose of the study, a total of 40 tooth-acrylic resin samples were equally divided into four groups (three test groups and one control group) consisting of ten samples each. The tooth-acrylic resin specimens of 20 mm X 17 mm dimensions were obtained from corresponding tooth-wax forms of similar dimensions made using poly vinyl chloride (PVC) pipes. 40 cross-linked acrylic first maxillary molars (twenty right and twenty left) were taken of a single manufacturer (Lactodont, Pyrax polymers, Roorkee, India) for the study. As stated by the manufacturer, all teeth were nonporous, dense, vacuum processed, single layered cross-linked acrylic teeth. In addition, the denture base resin used for the study was a thermo-polymerised polymethyl-methacrylate (PMMA) denture base polymer marketed as a powder containing > 93% PMMA with a monomer liquid containing a co-polymer of methyl-methacrylate such as ethylene glycol-dimethacrylate.

A line 1 mm occlusal to the ridge-lap surface of the tooth was marked on the palatal aspect using a digital vernier caliper (Mitutoyo Inc. Japan) and continued all around the tooth. The ridge-lap surfaces of each of the forty teeth were flattened to the designated level with a tungsten carbide acrylic bur and finished and polished with 1200-grit abrasive waterproof paper (Sankyo Rikagaku Co Ltd, Saitama, Japan). This step was carried out to obtain a flat uniform surface area available for bonding to the denture base resin.

These teeth were randomly selected irrespective of the sides to make 10 samples in each of the four groups desired to be tested. All 40 specimen teeth were then immediately transferred onto pre-formed cylindrical wax specimens. Acrylic teeth were placed on the wax cylindrical specimens with their long axis perpendicular to the bottom of the cylindrical wax forms. Prepared specimens were then invested in KAVO denture flask. Commercially-available heat cure denture base material (Trevalon, Dentsply India pvt ltd, Gurgaon, India) was used and conventional procedure of acrylization was carried out.

Upon successful retrieval of cured specimens, conventional finishing and polishing procedures, careful inspection of the tooth-acrylic junction was carried out to make sure that there was no overlap at the interface so as to accurately subject it to shear loading forces (Figure 1). All the specimens were stored in distilled water for 24 hours before subjecting them to bond strength evaluation.

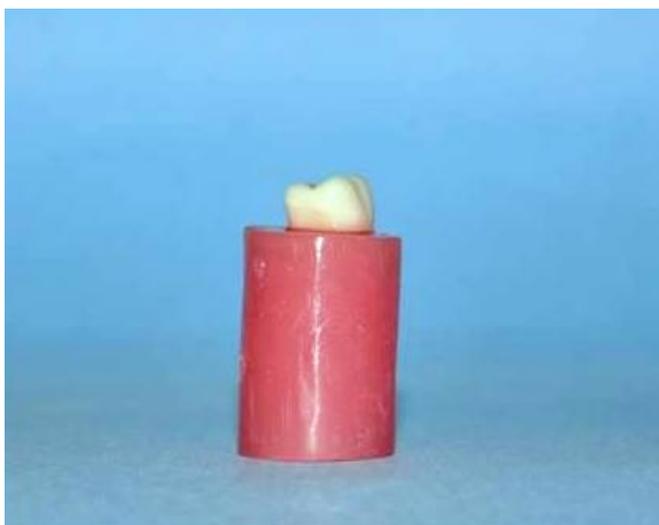


Figure 1: Resin-tooth specimen with a sharply defined junction

Based on the guidelines of Bragaglia [5] et al the present study was conducted, although few modifications were made and the shear load testing was carried out in the Universal testing machine (Instron 3366, UK) equipped with computer control, data acquisition and data analysis software (Bluehill software version 2.18.713). Prepared acrylic specimens were mounted on a specially designed fixates on the universal testing machine mounting table and shear load was applied at a cross-head speed of 0.5 mm /minute. During the testing, the fixture holding the acrylic resin-tooth sample was so aligned that the shearing blade was located exactly at the interface between the acrylic teeth and the denture base material on the buccal surface of the resin tooth. While performing the test, care was taken that shearing tool had low friction, sharp and hard edges and induced failure with no significant bending/rotation of the sample.

A flow-chart of the study design has been provided in figure 2.

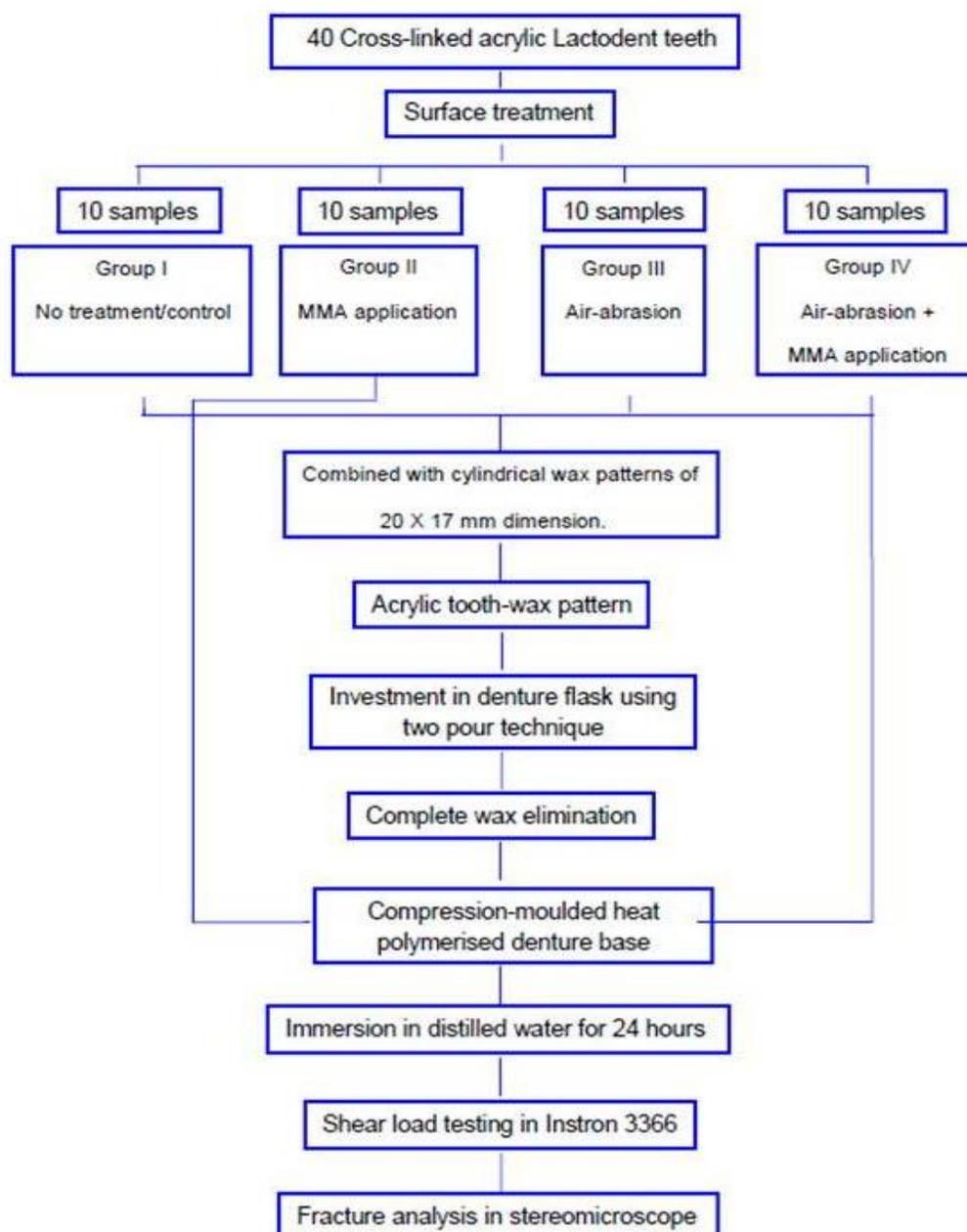


Figure 2: Study design

Fracture analysis of the interface

After the test specimens were fractured, the fracture surface was analysed by visual examination to determine whether the mode of failure was cohesive, adhesive or the specimen demonstrated a mixed failure. The failure was considered to be cohesive if more than 75% of the area of the failure surface was covered with a layer of either tooth resin or PMMA base material. The failure surfaces were subsequently examined under a stereomicroscope.

Statistical analysis

Numerical data was recorded for shear bond strength values (Kgf) for all specimens. On observation it was seen that there was skewing of data in all the four groups tested, with a wide difference in the maximum and the minimum values obtained in each group. This could be attributed to the mechanical testing error of the machine. Descriptive statistical analysis with the same data could have possibly resulted in greater statistical error. Hence, data values which showed greater than 15% deviation from the mean value for a particular group were eliminated from statistical analysis. Consequently, two values from each group were discarded and thus, statistical analysis was carried out for eight samples in each group. These values were considered to be more representative for respective groups.

Data was analyzed using statistical package SPSS (*IBM SPSS 16.0*). Mean values and standard deviations were calculated for the ultimate shear bond strength values for different test groups. One-way ANOVA test to determine any significant differences between the test groups was carried out. Subsequently, a Tukey's post-hoc analysis was conducted and results were expressed as maximum compressive load in Kgf and 'p' value ≤ 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

The ultimate shear strength value obtained amongst all the test groups was the highest (89.18 Kgf) for Group IV, thereby indicating the effect of combination of air-abrasion and MMA conditioning. Although the highest shear bond strength value seen in Group II (69.56 Kgf) was similar to Group III (69.29 Kgf), yet it was higher than highest value seen in Group I (54.65 Kgf). Subsequently, the mean shear strength values were computed. This value for Groups II, III and IV was numerically found to be higher than the mean bond strength value of the control group (Table 1).

Table 1: Shows descriptive analysis for each of the test groups showing mean shear bond strength values for each test group and also the 95% confidence limits for each.

Test Groups	n	Mean (Kgf)	Std Deviation	Std Error	95% CI (min. – max.)	Minimum (Kgf)	Maximum (Kgf)
GROUP 1	8	43.78	6.83	2.41	38.06 – 49.49	35.23	54.65
GROUP 2	8	57.24	7.74	2.74	50.77 – 63.71	42.41	69.56
GROUP 3	8	47.99	12.84	4.54	37.25 – 58.72	31.17	69.29
GROUP 4	8	64.05	18.09	6.39	48.92 – 79.18	38.61	89.18
TOTAL	32	53.26	14.13	2.49	48.17 – 58.37	31.17	89.18

Thus, all three pre-processing surface treatment modalities had a positive effect on mean shear strength of the denture tooth-base joint in comparison to the case in which no treatment was done.

The mean shear strength values obtained after measurement were subjected to one-way Analysis of Variance or one-way ANOVA test. There was a significant difference in mean maximum

compressive load among the 4 study groups depending upon the tooth surface conditioning carried out (*p < 0.05). Subsequently, Tukey's post hoc analysis was performed to evaluate the significant differences in between any of the 2 groups. Post hoc analysis revealed that Group IV had significantly higher mean compressive strength than Group I (Table 2). No significant differences were present in any of the group comparisons.

The fractured surfaces were also examined thoroughly in the stereomicroscope (*Moticam 2300*) in 25X magnification. The differing modes of failure seen at the fracture-interfaces of test specimens were then tabulated according to various test groups. A cross-tabulation of the incidence of varying modes of failures was also carried out in each of the four test groups (Table 3).

Table 2: Tukey's post-hoc analysis between various test groups to analyse significant pair differences.

Group (i)	Group (j)	Mean Difference (i-j)	Std Error	Significance	95% CI (min. – max.)
Group I	Group II	-13.46	6.11881	.148	-30.17 – 3.24
	Group III	-4.21	6.11881	.900	-20.92 – 12.49
	Group IV	-20.28	6.11881	.013	-36.99 – (-3.58)
Group II	Group I	13.46	6.11881	.148	-3.24 – 30.17
	Group III	9.25	6.11881	.444	-7.45 – 25.96
	Group IV	-6.81	6.11881	.684	-23.52 – 9.89
Group III	Group I	4.215	6.11881	.900	-12.49 – 20.92
	Group II	-9.25	6.11881	.444	-25.96 – 7.45
	Group IV	-16.07	6.11881	.063	-32.77 – 0.63
Group IV	Group I	20.28	6.11881	.013	3.58 – 36.99
	Group II	6.81	6.11881	.684	-9.89 – 23.5
	Group III	16.07	6.11881	.063	-.63 – 32.77

Table 3: Shows cross-tabulation between the modes of failure and different test groups depending on surface treatment performed.

Modes			GROUPS				Total
			Control	Monomer	Air-abrasion	Combination	
Cohesive	Count	3	6	4	6	19	
	% within modes	15.8%	31.6%	21.1%	31.6%	100.0%	
Mixed	Count	1	2	4	2	9	
	% within modes	11.1%	22.2%	44.4%	22.2%	100.0%	
Adhesive	Count	4	0	0	0	4	
	% within modes	100.0%	0%	0%	0%	100.0%	
Total	Count	8	8	8	8	32	
	% within modes	25.0%	25.0%	25.0%	25.0%	100.0%	

DISCUSSION

Bonding failures between artificial teeth and heat-polymerized denture base resins are a result of multitude of factors such as excessive stress, fatigue, insufficient tooth cleaning during denture base resin placement, wax and tinfoil substitute contamination, defective properties of materials [5,8,9,10] and inappropriate heat-polymerizing technique [5,11].

The strength of bond between the denture tooth and the denture base has been ascribed to a combination of factors [12]. Such factors have been investigated with different testing methods and the resulting data have been used to suggest technical procedures to enhance this bond.

The present study examined changes in the shear bond strength of a single brand of acrylic tooth with a denture base resin, after subjecting it to three differing modes of tooth-surface conditioning prior to conventional heat-processing procedures.

The ridge-lap surface of these cross-linked teeth was flattened to the designated level of 1 mm above the actual ridge-lap base to achieve a flat, uniform surface area of contact with the acrylic resin. Caswell *et al.* [13] in 1986 showed that reduction of the base of the tooth increased the depth of bond and overall tensile strength of the tooth. In accordance with available literature and the ADA specification 15 [14] for the same, this study also modified the ridge lap surface of all the teeth making sure that there was no cervical coverage of acrylic. On the contrary, Bragaglia *et al.*[5] believed in cervical coverage of the tooth as they found it clinically most realistic. However, cervical coverage of artificial teeth by denture base material in bond strength tests may be an inconvenience because the study variable (e.g.: surface treatment) may suffer the interference of mechanical retention.

Chemical modification of the ridge-lap area by application of methyl-methacrylate monomer is an accepted surface-treatment modality [3,7,15].

As stated by Nishigawa *et al.* [6] and other authors [16], free MMA in the dough-state resin causes the plastic tooth resin surface to swell up and dissolve, which promotes its adherence to the heat-cured acrylic resin. A factor of concern for such surface treatment is the MMA wetting time, which has been shown to be of much importance in adhesion between acrylic resins by Vallitu *et al.*[17] Varying MMA wetting-time protocols have been followed by investigators leading to differing results [3,7,17]. Bragaglia *et al.* [5] etched tooth bases twice with a methylmethacrylate monomer 10 min before acrylic resin packing and just before packing as a surface treatment regimen for their study. The same protocol was followed for the current study.

Chung et al.[7] in 2008 demonstrated significantly higher bond strength values of ridge-lap surfaces sandblasted with 250 μm alumina particles when processed with a thermo-polymerised acrylic resin. This result was attributed to micro-roughening of the surface which led to an increase in the surface area and surface energy thereby improving adhesion at the interface. Thus, micromechanical retention was put forth as a mechanism to explain the advantage of sandblasting treatment in improving bonding.

However, the results of studies in which this modality of surface treatment was carried out, as a method to improve bonding, have largely been contradictory; thus warranting the present investigation [5,6,18-21].

Also, the mode of polymerisation followed for the current study was a thermal mode. Old and recent studies [7,22] have shown numerically lower denture tooth-base bond strengths with microwave-polymerised specimens owing to uncontrolled temperature rise which results in formation of pores, especially in thicker areas. This is of clinical relevance as thickness of the denture base material in the tooth-bearing areas might promote pore formation. Unlike microwave polymerisation, thermal mode of polymerisation results in better mechanical properties of the denture and thus, is the most widely used method [23,24].

Bond strengths of various interfaces related to dental materials may be measured in terms of the ultimate shear strength, ultimate tensile strength, ultimate flexural strength or through photo-elastic analysis.

Although considered a reliable modality to test the desired mechanical variable, photo-elastic analysis is however, much dependent upon the homogeneity of the specimen [25]. Evaluation of bond strength through 3-point and 4-point flexural loading also, does not provide actual material property data. On the contrary, it provides accurate structural data dependent on inherent material and specimen geometry [25]. The tensile loads used in many artificial tooth bond strength studies are not representative of real conditions either. The anatomic shape of posterior teeth and the direction of occlusal forces make the occurrence of significant tensile forces over these teeth unlikely [26]. On the other hand, shear and compressive loads are much more plausible clinically, as carried out in a majority of studies including the current one. Ideally, the shear bond strength is calculated by measuring the bond surface area but in this study as in other recent studies, the same was not done due to complexity of the curves obtained.

In the current study, surface treatment of the ridge-lap surfaces by combination of air abrasion and application of 2 coats of MMA showed highest bond strength values in comparison to other modes of surface treatment (Group IV).

Furthermore, all modalities of surface treatment demonstrated numerically stronger bonds between tooth and denture base than non-treated samples; although not all were significantly strong. Conditioning of tooth surfaces with 2 coats of MMA liquid resulted in better shear bond strength than air abrading the ridge-laps with 110 μm alumina particles. These results were similar to the observations of Saavendra *et al.*[27] but in contrast to the conclusions of Consani *et al.* [28] This difference could be attributed to the fact that Consani *et al.*[28] conducted their study using microwave-polymerised denture base resin and varied MMA wetting time. As noted by Bragaglia *et al.*[5] through their investigation, this study also demonstrated insignificant results when MMA application and air-abrasion were carried out singly as opposed to the condition when they were used in combination.

Another objective of this study was to analyse and classify the mode of failure seen at the tooth-resin interface. Caswell *et al.*[13], Vallittu *et al.*[17] and Ward *et al.*[29] similarly analysed the modes of failure of the test specimens and classified them broadly into two categories: cohesive failure and adhesive failure. However, in the present study it was seen that the typical method of application of shear load on the buccal side of the tooth could possibly result in creation of wedging forces on the palatal side of the tooth Hence, mixed failure as a separate entity needs to be recognised as one of the modes of failure of the resin specimens.

Recently, Bragaglia *et al.* [5] devised a detailed classification of failure modes which included; adhesive, cohesive in PMMA denture base, cohesive in the tooth, cohesive in both and mixed failure. In the present study, mode of failure at the fractured site was classified into three main categories:

1. Adhesive failure with separation at the denture tooth-resin interface. (Figure 3)
2. Cohesive failure: It involved cohesive failure of the denture base resin and/or, cohesive failure of the acrylic tooth. (Figure 4)
3. Mixed failure: When significant areas of adhesive and cohesive failures occurred simultaneously. (Figure 5)



Figure 3: Stereomicroscopic image of a specimen showing adhesive failure

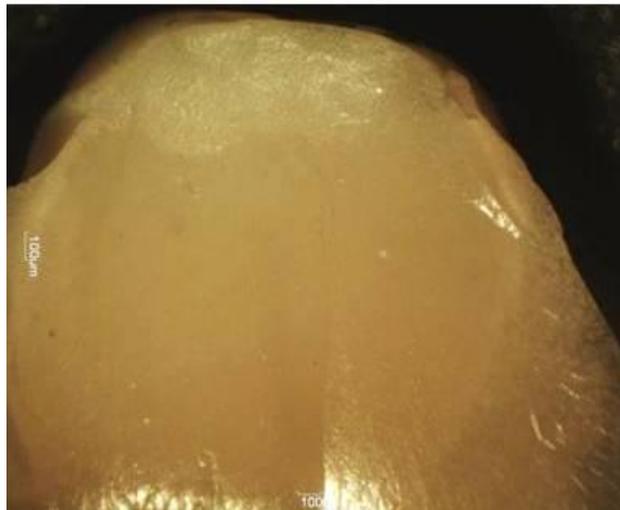


Figure 4: Stereomicroscopic image of a specimen showing cohesive failure.



Figure 5: Stereomicroscopic image of a specimen showing mixed failure

Group I showed an almost equal number of cohesive and adhesive failures with one sample showing a mixed type of failure. Thus, it can be stated that the bond between the untreated resin tooth and denture base was not sufficiently strong to withstand shear loading forces and hence a separation at the interface could be appreciated.

Groups II and IV on the other hand, demonstrated a 75% incidence of cohesive failures in addition to mixed failures respectively, thereby indicating an increase in bond strength of the tooth-resin junction. The stereomicroscopic examination of a sample revealed rough irregular areas of acrylic resin still bonded to the resin tooth covering more than 75% of total area examined. Group III however, exhibited an equal number of cohesive and mixed failures, thus confirming the increase in bond strength but clearly, it was not equivalent to the bond strength displayed by specimens in groups II and IV. Such a result is consistent with the observations of Ward et al [29].

Of all the cohesive failures seen, groups II and IV equally accounted for 31.6% of the total incidence and groups I and III showed 15.8% and 21.1% of occurrence respectively. Mixed type of failure was seen maximally in specimens belonging to group III while adhesive failure was exclusively demonstrated by specimens in group I.

This can be correlated well with the bond strength values obtained during testing of the specimens. It can be pointed out that as the shear bond strength of the specimen increases due to various surface treatments the probability of cohesive type of failure also increases. In simple terms, specimens that exhibit high shear bond strength values are more likely to show fracture within the denture base resin or resin tooth.

CONCLUSION

From the results obtained it can be concluded that, there was a significant effect produced on the shear bond strength of the interface only when both MMA application and air-abrasion of the ridge-lap surfaces was carried out. When done singly, these modalities showed numerically higher bond strength values but these values were not statistically significant in comparison to the control group in which no treatment was carried out. Also, application of MMA over the ridge-lap area yielded better results than air-abrasion with 110 μm alumina particles. Fracture analysis revealed that most of the specimens showed cohesive failure at the interface with adhesive failure restricted to control/group I exclusively.

CLINICAL SIGNIFICANCE

The current study was designed to delineate methods to improve the bonding of denture tooth to acrylic resin which still remains inconsistent and unreliable. In this study only shear stresses were

applied at the tooth-denture base interface. However, in a clinical scenario, such interfaces are subjected to cyclic masticatory loads with a combination of shear, tensile and flexural forces acting at any given point. Additionally, all specimens in this study were tested in a Universal testing machine which is prone to mechanical error. Furthermore, we believe that prospective studies should be performed to investigate the effects of using different denture base materials, tooth brands and materials, surface treatments, polymerizing parameters, thermocycling etc. on the mechanism of debonding.

AUTHOR DECLARATION

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors wish to disclose no financial, economic, commercial, or professional interests related to topics presented in the manuscript. We would also like to state that the manuscript has been read and approved by all the authors, that the requirements for authorship as stated in the guidelines have been met, and that each author believes that the manuscript represents honest work, if that information is not provided in another form.

We declare that the manuscript or portions thereof are not under consideration by another journal or electronic publication and the manuscript is not submitted or published elsewhere.

REFERENCES

1. Anusavice K. Resin teeth for prosthetic applications, denture base resins. In: Philip's science of dental materials, 11th edition. Mosby Elsevier publishing house, New Delhi, India, 2003; p 754.
2. A Brief Review: Biomaterials and their Application. Tathe A, Ghodke M, Nikalje AP. *Int J Pharm Pharm Sci* 2010;2(suppl 4):19-23.
3. Chaves CL, Regis RR, Machado AL, Souza RF. Effect of Ridge Lap Surface Treatment and Thermocycling on Microtensile Bond Strength of Acrylic Teeth to Denture Base Resins. *Braz Dent J* 2009; 20(2): 127-131.
4. Naveen BH, Kashinath KR, Mythri H, Hajirarare N. Rare but reality of methyl methacrylate in dentistry– a case study. *Int J Pharm Pharm Sci* 2014;6(6):39-40.
5. Bragaglia LE, Prates LHM, Calvo MCM. The Role of Surface Treatments on the Bond between Acrylic Denture Base and Teeth. *Braz Dent J* 2009; 20(2): 156-161.
6. Nishigawa G, Maruo Y, Okamoto M, Oki K, KInuta Y, Minagi S, et al. Effect of Adhesive Primer Developed Exclusively for Heat-curing Resin on Adhesive Strength between Plastic Artificial Tooth and Acrylic Denture Base Resin. *Dental Materials Journal* 2006; 25(1): 75–80.

7. Chung KH, Chung CY, Chung CY, Chan DC. Effect of pre-processing surface treatments of acrylic teeth on bonding to the denture base. *J Oral Rehab* 2008; 35: 268-275.
8. Clancy JM, Boyer DB. Comparative bond strengths of light-cured, heat-cured, and autopolymerizing denture resins to denture teeth. *J Prosthet Dent* 1989; 61: 457-462.
9. Clancy JM, Hawkins LF, Keller JC, Boyer DB. Bond strength and failure analysis of light-cured denture resins bonded to denture teeth. *J Prosthet Dent* 1991; 65: 315-324.
10. Huggett R, John G, Jagger RG, Bates JF. Strength of the acrylic denture base tooth bond. *Br Dent J* 1982; 153: 187-190.
11. Schneider RL, Curtis ER, Clancy JM. Tensile bond strength of acrylic resin denture teeth to a microwave - or heat – processed denture base. *J Prosthet Dent* 2002; 88: 145-150.
12. Albarghouty H, Juszczak AH, Radford DR, Clark RKF. Tensile Bond Strength of Heat and Self-Cured Acrylic Denture Base Resins to the Inner and Outer Layers of Two-Layered Acrylic Resin Denture Teeth. *Eur. J. Prosthodont. Rest. Dent.* 2007;15(2):81-83.
13. Caswell CW, Norling BK. Comparative study of the bond strength of the abrasion-resistant plastic denture teeth bonded to a cross-linked and a grafted, cross-linked denture base material. *J Prosthet Dent* 1986; 55: 701–708.
14. Revised ANSI/ADA specification 15 for synthetic resin teeth. *Am Dent Assoc* 1985; 119-131.
15. Cunningham JL. Shear bond strength of resin teeth to heat-cured and light- cured denture base resin. *J Oral Rehabil* 2000; 27: 312-316.
16. Prosthetic applications of polymers. p 544-546. In, *Craig's Restorative dental materials*, 12th edition. Powers JM, Sakaguchi RL. Mosby Elsevier publishing house. New Delhi, India.
17. Vallittu PK. Bonding of resin teeth to the polymethyl methacrylate denture base material. *Acta Odontol Scand*, 1995; 53: 99-104.
18. 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: 164–170.
19. El-Sheikh MM, Powers JM. Tensile bond strength of porcelain teeth to denture resin before and after aging. *Int J Prosthodont.* 1998; 11: 16–20.

20. Takahashi Y, Chai J. Assessment of shear bond strength between three denture reline materials and a denture base acrylic resin. *Int J Prosthodont*. 2001;14: 531–535.
21. Husham AM, Al-Bazirgan MHK. Effects of air-particle abrasion on the retention and texture of the maxillary complete denture. *Am Dent J*. 2006; 19: 115–122.
22. Polyzois GL and Dahl JE. Bonding of synthetic resin teeth to microwave or heat activated denture base resin. *Eur J Prosthodont Rest Dent*,1993;2:41-44.
23. Hayden WJ. Flexural strength of microwave-cured denture baseplate. *Gen Dent* 1986; 34: 367-371.
24. Lai CP, Tsai MH, Chen M, Chang HS, Tay HH. Morphology and properties of denture acrylic resins cured by microwave energy and conventional water bath. *Dent Mater*. 2004 Feb; 20(2): 133-141.
25. Bhat VS, Nandish BT. General properties of matter. In: *Science of dental materials*, 1st edition. CBS publishers and distributors. New Delhi, India; 37-39.
26. Darbar UR, Huggett R, Harrison A and Williams K. The tooth-denture base bond: stress analysis using the finite element method. *Eur J Prosthodont Rest Dent*, 1993; 1: 117-120.
27. Saavedra G, Valandro LF, Leite FPP, Amaral R, Ozcan M, Bottino MA, et al. Bond strength of acrylic teeth to denture base resin after various surface conditioning methods before and after thermocycling. *Int J Prosthodont* 2007; 20: 199-201.
28. Consani RL, Naoe HT, Mesquita MF. Effect of ridge-lap surface treatments on the bond of resin teeth to denture base. *J Adhesive Dent* 2011; 13; 287-293.
29. Ward JE, Moon PC, Levine RA. Effect of repair surface design, repair material and processing method on the transverse strength of the repaired acrylic denture resin. *J Prosthet Dent*. 1992; 67: 815-820.

AJPTR is

- Peer-reviewed
- bimonthly
- Rapid publication

Submit your manuscript at: editor@ajptr.com

