ISSN - 2394-7721

American Journal of Oral Medicine and Radiology

Journal homepage: www.mcmed.us/journal/ajomr

INFLUENCE OF SURFACE TREATMENTS ON SHEAR BOND STRENGTH BETWEEN COMPOSITE RESIN AND ACRYLIC RESIN DENTURE TEETH-AN IN VITRO STUDY

Ginnia Bhayana[1], Nidhi Duggal[2], Gaurav Atreja[1], Ashish Juneja[3], Arun Kumar[4]

[1]Department of Prosthodontics, [3]M.M.University of Dental Sciences and Research, Mullana, Ambala, Haryana, India.
[2]Department of Prosthodontics, Government Dental College & Hospital, Patiala, Punjab, India.
[4] Department of Pedodontics & Preventive Dentistry, Post Institute of Dental Sciences, Rohtak, Haryana, India.

Article Info

Received 23/06/2015
Revised 16/07/2015
Accepted 19/08/2015

Key words:- Surface treatments, shear bond strength, composite resin, acrylic resin.

ABSTRACT

Visible light activated composite resins are preferred for various prosthodontic applications as restoration of fractured or deboned artificial teeth because of the advantages of excellent aesthetics, superior colour stability, improved wear resistance and minimum inconvenience to the patients. However, the bonding of composite resin to acrylic resin denture teeth has remained unpredictable. Various methods as acid etching, air abrasion, use of solvents or bonding agents have been reported to improve the bond strength of these two resins. But there is no consensus on the results obtained with different surface treatments. The purpose of this study is to evaluate the efficacy of different combinations of surface treatments used to improve the bond strength between light activated composite resin and acrylic resin denture teeth. Ninety test specimens of acrylic resin denture teeth of the same mold were prepared and divided into six groups, containing 15 samples each. The denture teeth were subjected to six different combinations of surface treatments including acid etching with 35% phosphoric acid, application of methyl methacrylatre, bonding agent, aluminium oxide powder and flowable composite. Over all treated surfaces, light activated composite resin was applied in increments and cured. The shear bond strength of composite resin to acrylic resin denture teeth was determined and analyzed statistically.

INTRODUCTION

Fracture or detachment of acrylic resin denture teeth from the denture bases is a frequent and unresolved clinical problem in Prosthodontics, accounting for 20-33% of denture repairs. Artificial teeth may fracture or debond due to excessive biting forces in the mouth, fatigue failure, stress concentration, accidental trauma etc. It is desirable that not only the material used for repair of artificial denture teeth should match the original material in strength and shade but also the technique employed should be easy, quick and inexpensive.

Corresponding Author

Arun Kumar
Email: - drarun922@gmail.com

Autopolymerising acrylic resin, heat cured acrylic resins and more recently, visible light cured composite resins have been proposed for replacement of fractured or debonded denture teeth. Usually, the immediate in-office repair with autocured acrylic resins have inferior colour stability and the use of heat cured acrylic resins require time consuming laboratory procedures. Hence, visible light cured composite resins have been advocated for repair and modification of acrylic resin teeth because these offer excellent aesthetics, superior wear resistance, minimal inconvenience to the patients and also eliminates the need for costly and time consuming procedures. Other applications of composite resins include esthetic modification of shade, size or shape of acrylic resin teeth, fabrication of composite resin teeth on partial denture metal frameworks, correction of worn occlusal contacting surfaces of posterior artificial teeth.

However, an adequate bond between composite resin and acrylic resin denture tooth which is essential for the success or longevity of these procedures has remained unreliable, inconsistent and unpredictable. Various surface treatments like acid etching, air abrasion, use of methyl methacrylate monomer, chloroform, acetone, silanes, bonding agent, flowable composite resins have been advocated to enhance the bond strength between composite resin and acrylic resin denture teeth.

Most of the studies have demonstrated that a bonding agent is essential for achievement of an adequate bond strength between the light-activated and heat polymerised resin. As regards the use of methyl methacrylate monomer, conflicting results have been reported. Lagouvardos et a[9] and Lucena et al[10] observed that surface treatment with air abrasion along with bonding agent had a synergistic effect on the bond strength of composite resin to artificial teeth. Considerable variations in the bond strength values have been reported in the literature.

So, a study has been planned to compare the efficacy of various surface treatments on the bond strength between composite resin and acrylic resin denture teeth so as to identify an optimal surface treatment which can enhance bonding.

MATERIALS AND METHODS

The study was conducted on ninety mandibular first molar acrylic resin denture teeth of the same mould.

The denture tooth will be mounted on to a rectangular wax mould (Fig.1). Wax mould with embedded acrylic denture tooth will then be invested in dental plaster (Fig.2). After setting of plaster and dewaxing, the mould space will be packed with heat cured acrylic resin and polymerized (Fig.3). The test specimen will then be cooled to room temperature, deflasked and finished.

Denture Tooth Preparation

The attached denture tooth will be milled to a diameter of 6mm (Fig.4) to standardize the bond surface area (Fig.5).

Ninety such specimens will be prepared and stored in distilled water for one week, cleaned and dried. These will be divided into six groups with each group containing fifteen test specimens.

Groups : Surface Treatment of Acrylic Resin Denture Teeth

Group 1. Acid etching (35 % phosphoric acid) and Bis- GMA based bonding agent application.

Group 2. Methyl methacrylate monomer and Bis- GMA based bonding agent application.

Group 3. Acid etching (35 % phosphoric acid), methyl methacrylate monomer and Bis - GMA based bonding agent application.

Group 4. Air abrasion with 50 *um* aluminium oxide and Bis- GMA based bonding agent application.

Group 5. Air abrasion with 50*um* aluminium oxide, acid etching (35% phosphoric acid) and Bis- GMA based bonding agent application.

Group 6. Acid etching (35 % phosphoric acid), Bis-GMA based bonding agent and flowable composite application.

Over all the treated surfaces of acrylic resin teeth, light activated composite resin of 4mm thickness was applied in increments and cured (Fig.6). After polymerisation, test specimens were stored in distilled water at room temperature for 7 days before testing.

Testing Procedure

The shear bond strength between composite resin and acrylic resin denture teeth was measured in a Universal Testing Machine (Instron) using a knife-edge shear test (Fig.7). A load parallel to the acrylic resin denture tooth and composite resin interface at a crosshead speed of 0.5 mm/minute was applied. The maximum load, at break, for each specimen (Fig.8) was divided by bonding area (mm^2), to express the shear bond strength. i.e. 'σ'(MPa) = L/A,

Where 'σ' stands for shear bond strength (MPa)

L stands for load (N) required to cause fracture at composite resin-acrylic resin denture tooth interface.

A is the interfacial area (mm^2), which is calculated using the formula:

'A' = πr^2, where 'r' is 3 mm.

The results thus obtained will be analysed statistically.

OBSERVATIONS AND RESULTS

Table 1 depicts the values of the shear bond strength in 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 (Fig. 9)

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.

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

A. Surface treatment with air abrasion, etchant and bonding agent (Group 5) exhibited significantly higher mean bond strength (43.0847 MPa) than the other groups.

B. The mean bond strength values for teeth treated with etchant, MMA monomer and bonding agent (Group 3) was statistically significantly greater than the teeth in Group 2 (methylmethacrylate monomer and bonding agent). Addition of etchant in Group 3 might have created greater roughening of the acrylic resin surface and hence improved bond strength.

C. Group 1 (etchant and bonding agent application), Group4 (air abrasion and bonding agent), Group6 (etchant, bonding agent and flowable composite application) demonstrated significantly higher mean bond strength values than group 2 (MMA monomer and bonding agent) which exhibited the least mean bond strength.

Figure 1. Wax blocks with mounted acrylic resin denture teeth.

Figure 2. Teeth embedded in the plaster adjacent to mould space (after dewaxing)

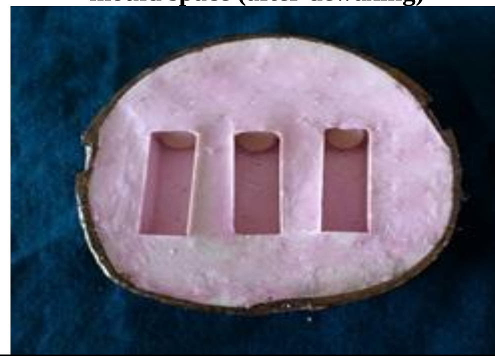

Figure 3. Packing of heat-cure acrylic resin material

Figure 4. Acrylic resin denture tooth milled to a diameter of 6mm

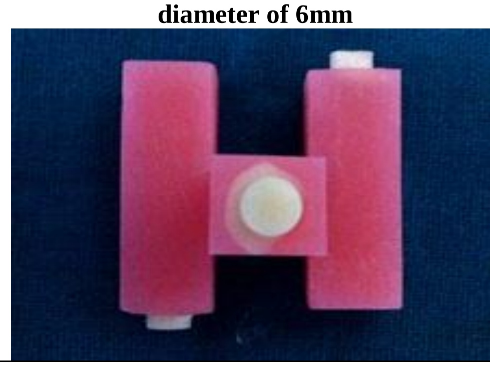

Figure 5. Air-abrasion of acrylic resin denture tooth in sandblasting machine

Figure 6. Light curing of composite resin placed over treated surfaces of acrylic resin denture tooth

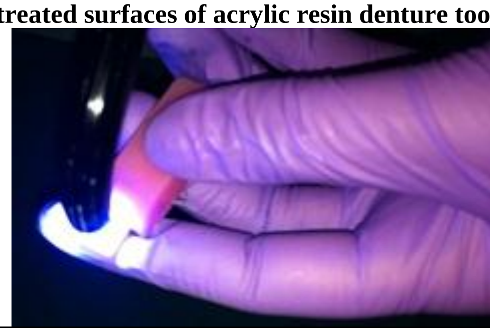

Figure 7. Test specimens in Universal Testing Machine

Figure 8. Fracture at the interface of composite resin and acrylic resin denture teeth.

Figure 9. bar diagram showing values of shear bond strength

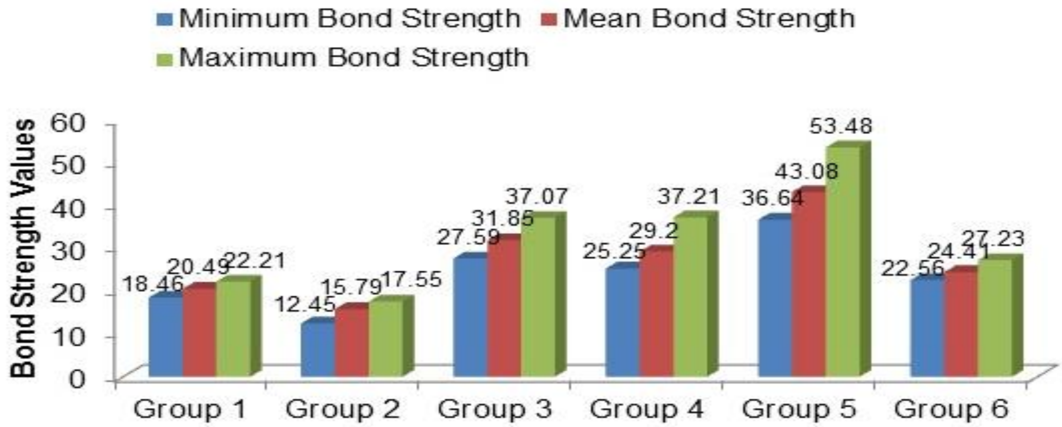

Table 1. Shear Bond Strength (MPa) of Individual Test Specimens

Specimen No.	Treatment Group 1	Treatment Group 2	Treatment Group 3	Treatment Group 4	Treatment Group 5	Treatment Group 6
1	18.46 MPa	16.83 MPa	29.92 MPa	25.53 MPa	50.01 MPa	27.23 MPa
2	21.08 MPa	16.20 MPa	29.85 MPa	27.80 MPa	42.94 MPa	24.12 MPa
3	20.09 MPa	15.28 MPa	27.59 MPa	26.38 MPa	53.48 MPa	25.25 MPa
4	19.38 MPa	15.63 MPa	30.06 MPa	28.22 MPa	48.60 MPa	23.91 MPa
5	21.01 MPa	15.91 MPa	29.57 MPa	26.18 MPa	49.94 MPa	22.56 MPa
6	21.22 MPa	17.19 MPa	33.25 MPa	37.21 MPa	47.18 MPa	23.27 MPa
7	20.80 MPa	16.41 MPa	37.07 MPa	34.59 MPa	41.17 MPa	23.13 MPa
8	19.81 MPa	14.29 MPa	31.97 MPa	29.57 MPa	39.54 MPa	26.46 MPa
9	18.74 MPa	17.55 MPa	34.02 MPa	26.03 MPa	39.40 MPa	24.76 MPa
10	19.88 MPa	15.56 MPa	30.27 MPa	29.92 MPa	39.76 MPa	24.12 MPa
11	21.01 MPa	16.90 MPa	33.74 MPa	27.23 MPa	39.47 MPa	23.98 MPa
12	21.57 MPa	14.71 MPa	29.98 MPa	25.25 MPa	40.04 MPa	22.63 MPa
13	20.72 MPa	17.26 MPa	35.44 MPa	29.85 MPa	39.12 MPa	26.03 MPa
14	21.50 MPa	12.45 MPa	33.40 MPa	33.25 MPa	38.98 MPa	23.84 MPa
15	22.21 MPa	14.71 MPa	31.65 MPa	31.05 MPa	36.64 MPa	24.90 MPa

Table 2. Showing Mean and Standard Deviation Values of Shear Bond Strength

Test Groups	N	Minimum	Maximum	Mean	Standard Deviation	Standard Error	95% Confidence Interval For Mean	
							Lower Bound	Upper Bound
Test Group No.1	15	18.46	22.21	20.4987	1.0732	0.2771	19.9043	21.093
Test Group No.2	15	12.45	17.55	15.792	1.36738	0.35305	15.0348	16.5492
Test Group No.3	15	27.59	37.07	31.852	2.5788	0.66584	30.4239	33.2801
Test Group No.4	15	25.25	37.21	29.204	3.55678	0.91836	27.2343	31.1737
Test Group No.5	15	36.64	53.48	43.0847	5.26123	1.35844	40.1711	45.9982
Test Group No.6	15	22.56	27.23	24.4127	1.37072	0.35392	23.6536	25.1717
Total	90	12.45	53.48	27.474	9.26002	0.97609	25.5345	29.4135

Table 3. Analysis of Variance (ANOVA)

Source	Sum of Squares	Degree of freedom	Mean of Squares	'F'	Sig.
Between Groups	6905.233	5	1381.047	159.715	O.OOO**
Within Groups	726.344	84	8.647		
Total	7631.577	89			

** Since the mean difference in the present study lies between 0.00 and 0.01, findings of the present study are highly significant i.e. all the six combinations of surface treatments show statistically significant difference in the bond strength values.

DISCUSSION

True adhesion has been the "Holy Grail" of dental restorative materials since decades. As with any bonding process, the bond strength of an adherent material to another is dependent on its ability to establish an intimate contact and form some kind of physical (electrostatic bonding), chemical (atomic or molecular bonding) or mechanical (material interlocking) bond at the interface. Indeed a combination of all these three types produces the strongest bond. When the adhesive joint consists of a ground denture tooth surface on one side (adherend or substrate) and the composite resin on the other side (adherent or adhesive), the surface conditioning of the adherend plays a pivotal role in adhesion between the two resins.

Various surface conditioning methods as acid etching, air abrasion, use of methylmethacrylate monomer, chloroform, acetone, silanes, bonding agent, flowable composite resins have been advocated to enhance the adhesion but the optimum surface conditioning method has never obtained consensus. Hence, the present study had been undertaken to compare the efficacy of various surface treatments on the bond strength between composite resin and acrylic resin denture teeth so as to identify an optimum surface treatment which would enhance bonding and could be recommended for the clinical success and longevity of the prostheses or restorations.

Bis-GMA based bonding agent was used as one of the components of all the surface treatment modalities investigated in the present study and it was observed that the range of bond strength values achieved with various surface treatments was between 15.79 and 43.08 MPa. Perhaps the bonding agent in addition to increasing micromechanical retention helped in the formation of chemical bond between the matrix and exposed filler particles and hence enhanced the bond between acrylic resin denture teeth and composite resin after various surface treatments.

Another surface treatment method employed in this study was air-abrasion with 50 µm Al_2O_3 in combination with bonding agent and / or etchant. The results of the present study exhibited that surface treatment with air abrasion, etchant and bonding agent (Group-5) achieved the highest bond strength value (43.08 ± 5.26 MPa). The bond strength of the test specimens in Group-4 (air abrasion and bonding agent) was also in significantly acceptable range i.e. 29.20 ± 3.55 MPa. The increased bond strength can be ascribed to the fact that sandblasting increased the surface area available for physical and chemical bonding between acrylic resin teeth and composite resin. Also, the air-abrasion might have removed the saturated surface layer and exposed the underneath layer with a higher surface energy. This would have improved the wettability of the acrylic resin denture teeth and hence enhanced the bond strength.

However, Guzman A. and Moore B.K.[6] observed that if the bonding agent recommended with the light-activated composite resin was used, additional treatment with airborne particle abrasion did not significantly improve bond strength between light-activated composite resin and heat-polymerized resin.

But the results of the present study revealed that the use of combination of etchant and bonding agent produced bond strength of 20.49 ± 1.07 MPa. The addition of air particle abrasion to etchant and bonding agent resulted in a highly statistically significant improvement in the bond strength from 20.49 ± 1.07 MPa to 43.08 ± 5.26 MPa. Even the combination of air-abrasion and bonding agent as surface treatment demonstrated statistically significantly higher mean bond strength (29.20 ± 3.55 MPa) than the combination of etchant and bonding agent (20.49 ± 1.07 MPa). Superior bond strength achieved with sandblasting might have been not only due to further increase in surface area and surface energy but also because of the embedding of alumina particles in the surface resulting in greater micromechanical retention.

Surface treatment with etchant, bonding agent and flowable composite (Group 6) significantly enhanced the bond strength value (24.41 ± 1.37 MPa) in comparison to use of etchant and bonding agent only (20.50 ± 1.07 MPa). The explanation lies with the ability of flowable composite resin to mediate a closer contact of condensing composite with the tooth surface. This technique seems to be a good alternative procedure in cases where the condensing material is rather stiff and an abrasive unit is not available.

Acrylic resin denture teeth are mainly composed of polymethylmethacrylate and polyethylmethacrylate. Because of the manufacturing process (heat curing and cross-linking), the degree of conversion is relatively high in acrylic resin denture teeth. It has been suggested that wetting of the heat polymerized acrylic resin surfaces with methylmethacrylate for three minutes improves the bonding as it dissolves the surface structure of polymethylmethacrylate. This provides free double bonds that can copolymerize with the composite material. As the polymerization process of methylmethacrylate and Bis-GMA follow a similar pattern of activation and cross-linking because of the similar reactive methacrylate group of molecules, some chemical bonding between composite and acrylic resin may 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. Rather, methylmethacrylate monomer may swell the denture tooth, allowing the composite to penetrate into surface microirregularities and yielding a mechanical bond. In reality, there is probably a combination of chemical and mechanical bonding between the composite and the monomer treated acrylic denture teeth.

Surface treatment with a combination of methylmethacrylate monomer and bonding agent used in the present study exhibited the least bond strength i.e. 15.79±1.36 MPa as compared to other surface conditioning modalities. The results indicate that the use of monomer to soften the acrylic resin denture teeth perhaps did not provide sufficient active sites to react with composite resin. Also, the poor wettability property of the high viscosity composite material probably influenced the result in Group-2 (Monomer and Bonding agent). But even the minimum value (15.79 ± 1.36 MPa) of bond strength exhibited by surface treatment with monomer and bonding agent was comparable to the bond strength value essential for the longevity of the bond between composite resin and etched enamel (10 MPa to 21 MPa).

Although this in vitro study evaluated the effect of different surface treatments on the bond strength between acrylic resin denture teeth and composite resin, it does not simulate the ideal clinical conditions as dentures are exposed to the forces due to functional (mastication and deglutition) and parafunctional activities in warm and wet oral conditions. The use of simple rectangular shaped specimens rather than a complex denture design contributes further to the limitations of the present study and should be investigated in future. Though the experimental method does not exactly imitate the intraoral conditions, it does provide an effective means of comparing the influence of six different surface treatments on the shear bond strength between acrylic resin denture teeth and composite resin under controlled conditions.

CONCLUSION

On the basis of results and conditions of this study, following conclusions were drawn:

1) Surface treatment with a combination of air-abrasion, etchant and bonding agent application exhibited highest bond strength i.e 43.08± 5.26 MPa between acrylic resin denture teeth and composite resin.

2) The shear bond strength achieved with surface treatment using etchant, monomer and bonding agent was 31.85±2.57 MPa and with air-abrasion and bonding agent was 29.20±3.55 MPa.

3) The bond strength between composite resin and acrylic resin denture teeth after surface treatment with a combination of etchant and bonding agent was 20.49±1.07 MPa. Addition of flowable composite resin further improved the bond strength to 24.41±1.37 MPa.

4) Surface treatment with a combination of methylmethacrylate monomer and bonding agent exhibited the least bond strength i.e. 15.79±1.36 MPa as compared to other surface conditioning modalities.

In light of these findings, it has been observed that all the six different combinations of surface treatments investigated in the study were effective in producing an optimum bond between acrylic resin denture teeth and visible light cured composite resin. The shear bond strength values achieved with all the surface conditioning methods used were significantly higher or comparable to the bond strength values considered adequate for the successful durable bond between composite resin and human enamel (10 MPa to 21 MPa).

As per this study, a combination of air abrasion, acid etching and bonding agent appears to be the most promising method of surface conditioning to enhance the composite resin-acrylic resin denture teeth bond essential for the success and longevity of a restoration and prosthesis. In case of non-availability of air abrasion unit, a combination of other surface treatments used in this study may be employed as an alternative procedure to achieve an adequate bond between composite resin and acrylic resin denture teeth.

ACKNOWLEDGEMENT: NIL

CONFLICT OF INTEREST: NIL

REFERENCES

1. Amarnath GS, Kumar HIS, Muddugangadhar BC. (2011). Bond strength and tensile strength of surface treated resin teeth with microwave cured and heat cured acrylic resin denture base: An in-vitro study. *International Journal of Clinical Dental Science*, 2(1), 27-32.
2. Bragaglia LE, Prates LHM, Calvo MCM. (2009). The role of surface treatments on the bond between acrylic denture base and teeth. *Braz Dent J*, 20(2), 156-161.
3. Chang JC, Katz ST. (1994). Composite denture teeth made on a removable partial metal framework. *J Prosthet Dent*, 71(4), 409-412.
4. Chatterjee N, Gupta TK, Banerjee A. (2011). A study on effect of surface treatments on the shear bond strength between composite resin and acrylic resin denture teeth. *J Indian Prosthodont Soc*, 11(1), 20-25.

5. Erkut S, Yilmaz B, Bagis B, Kucukesmen C, Ozdemir E, Acar O. (2014). Effect of different surface-cleaning techniques on the bond strength of composite resin restorations. *J Prosthet Dent*, 112(4), 949-956.
6. Guzman A, Moore BK. (1995). Influence of surface treatment on bond strength between a Heat-activated and a Light-activated resin composite. *The Int J Prosthodont*, 8(2), 179-186.
7. Hara AT, Pimenta LAF, Jr. Rodrigues AL. (2001). Influence of cross-head speed on resin-dentin shear bond strength. *Dental Materials*, 17, 165-169.
8. Junior SAR, Ferracane JL, Bona AD. (2009). Influence of surface treatments on the bond strength of repaired resin composite restorative materials. *Dental Materials*, 25, 442-451.
9. Lagouvardos PE, Polyzois GL. (2003). Shear bond strength between composite resin and denture teeth: Effect of tooth type and surface treatments. *The Int J Prosthodont*, 16(5), 499-504.
10. Martín CL, López SG, Mondelo JMNRD. (2001). The effect of various surface treatments and bonding agents on the repaired strength of heat- treated composites. *J Prosthet Dent*, 86, 481-488.
11. Mujdeci A, Gokay O. (2004). The effect of airborne-particle abrasion on the shear bond strength of four restorative materials to enamel and dentin. *J Prosthet Dent*, 92(3), 245-249.
12. Papazoglou E, Vasilas AI. (1999). Shear bond strengths for composite and autopolymerised acrylic resins bonded to acrylic resin denture teeth. *J Prosthet Dent*, 82(5), 573-578.
13. Perea L, Matinlinna JP, Tolvanen M, Lassila LV, Vallittu PK. (2014). Monomer priming of denture teeth and its effects on the bond strength of composite resin. *J Prosthet Dent*, 112(2), 257-266.
14. Renne W. (2010). Chairside repair of worn or lost denture teeth using nanofilled composite resin bonded to the denture base. *J Prosthet Dent*, 103(2), 129-130.
15. Saavedra G, Neisser MP, Sinhoreti MAC, Machado C. (2004). Evaluation of bond strength of denture teeth bonded to heat polymerised acrylic resin denture bases. *Braz J Oral Sci*, 3(9), 458-464.
16. Saavedra G, Valandro LF, Leite FPP, Amaral R, Ozcan M, Bottino MA, Kimpara ET. (2007). Bond strength of acrylic teeth to denture base resin after various surface conditioning methods before and after thermocycling. *International Journal of Prosthodontics*, 20(2), 199-201.
17. Sarac YS, Sarac D, Kulunk T, Kulunk S. (2005). The effect of chemical surface treatments of different denture base resins on the shear bond strength of denture repair. *J Prosthet Dent*, 94(3), 259-266.
18. Vergani CE, Giampaolo ET, Cucci ALM. (1997). Composite occlusal surfaces for acrylic resin denture teeth. *J Prosthet Dent*, 77(3), 328-331.
19. Vergani CE, Machado AL, Giampaolo ET, Pavarina AC. (2000). Effect of surface treatments on the bond strength between composite resin and acrylic resin denture teeth. *Int J Prosthodont* 13(5), 383-386.
20. Weiner S, Krause AS, Nicholas W. (1987). Esthetic modification of removable partial denture teeth with light–cured composites. *J Prosthet Dent*, 57(3), 381-384.