Frontiers in Dentistry

Comparison of Bond Strength of Acrylic, Composite, and Nanocomposite Artificial Teeth to Heat-Cure Acrylic Denture Base Resin

Tahereh Ghaffari Gharebagh[1], Fahimeh Hamedirad[2*], Keyvan Miruzadeh[3]

1. Department of Prosthodontics, Dental Faculty of Tabriz University of Medical Sciences, Tabriz, Iran
2. Dental Materials Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, Iran
3. Dentist, Dental Faculty of Tabriz University of Medical Sciences, Tabriz, Iran

Article Info

Article type:
Original Article

Article History:
Received: 26 June 2018
Accepted: 5 January 2019
Published: 29 June 2019

**** Corresponding author:***

Dental Materials Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, Iran

E-mail: fahimeh.hamedirad@gmail.com

A B S T R A C T

Objectives: The present study aimed to evaluate the bond strength of heat-cure denture base resin to newly designed Iranian artificial acrylic teeth.

Materials and Methods: In this in-vitro experimental study, shear bond strengths of Ivoclar acrylic, Apple composite, and B-Star nanocomposite teeth to heat-cure acrylic denture base resin were compared. A total of 18 samples were selected from each group of teeth. The samples were attached to heat-cure resin according to ISO 10477 standard. For the assessment of bond strength, the samples were placed in a universal testing machine and were subjected to shear forces at a speed of 1 mm/minute to record the fracture load. Descriptive statistics, including frequency, mean, and standard deviation, were calculated using SPSS 20 software. Two-way analysis of variance was used to compare the shear bond strength of the groups with and without monomers and the studied artificial teeth.

Results: The mean shear bond strengths of Ivoclar acrylic teeth were 392.22±23.76 MPa and 337.11±32.18 MPa with and without adding monomers to the tooth surface, respectively. The mean shear bond strengths were 250.44±29.84 MPa and 238.33±27.28 MPa (without monomers) and 438.33±24.16 MPa and 311.56±32.78 MPa (with monomers) for Apple composite and B-Star nanocomposite artificial teeth, respectively.

Conclusion: The greatest shear bond strength was attributed to Ivoclar acrylic teeth followed by Apple composite and B-Star nanocomposite artificial teeth. Addition of monomers to the tooth surface significantly strengthened the shear bonding of acrylic base resin to the teeth.

Keywords: Denture Bases; Acrylic Resins; Shear Strength; Artificial Teeth

➢ **Cite this article as:** Ghaffari Gharebagh T, Hamedirad F, Miruzadeh K. Comparison of Bond Strength of Acrylic, Composite, and Nanocomposite Artificial Teeth to Heat-Cure Acrylic Denture Base Resin. *Front Dent.* 2019;16(3):166-172. doi: 10.18502/fid.v16i3.1587

INTRODUCTION

Acrylic teeth are commonly used in the design of complete and partial removable dentures [1,2]. Comparison of acrylic and porcelain artificial teeth indicates that acrylic teeth chemically bond to the denture base material and are simpler to adjust [3]. Deboning of teeth from the denture base is a common cause of denture repair, accounting for 25% to 33% of failures [4]. Several factors can influence the bond strength between the teeth and denture base, including contamination with wax and thin foil [5,6], petrolatum and sodium alginate remaining on the ridge-lap surface of artificial teeth [7], inaccurate use of separating materials during curing, inadequate use of monomers for curing, improper methods used for denture base curing, inadequate mechanical or chemical preparation of tooth surfaces, absorption of water by resins, differences in the thermal expansion coefficient of artificial teeth and base material, and porosity on the border of denture base resin and teeth [8].

The physical and chemical properties of artificial teeth are effective in strengthening the bond to denture base resins [9,10]. On the other hand, this bond is affected by the physical and chemical properties of acrylic resins [2,3,11], polymerization temperature [10], and the method of artificial tooth preparation [3]. Various strategies have been proposed to increase the bond strength of artificial teeth to acrylic resins, such as the application of methyl methacrylate (MMA) monomers and wax solvents [12,13]. Bond strength has been shown to improve using different methods of artificial tooth surface treatment, including the use of MMA monomers, composite bonding materials, and acid-etching [3].

There are different types of artificial teeth, including methacrylate base resin, composite resin, and porcelain teeth, each with its advantages and disadvantages. Previous studies have reported different results on the bond strength of artificial teeth to base resins, depending on the type of resin, teeth, and test methods. Some studies have reported the bond strength of artificial teeth to heat-cure resins to be higher than that to the self-cure type [14,15]. Other studies have indicated that the bond strength of composite teeth to the acrylic base material is higher than that of acrylic teeth [16]. In contrast, some studies have revealed that the bond strength of acrylic teeth is higher than that of composite teeth [15-17].

Recently, Ideal Makoo Company, Makoo, Iran, has manufactured a group of artificial teeth. This company has presented new nanocomposite artificial teeth to the market with aesthetic advantages; however, there is no information about the bond strength of these teeth to acrylic denture bases. Therefore, the present study was conducted to evaluate the bond strength of Ideal Makoo composite and nanocomposite teeth to heat-cure acrylic denture base resin in comparison with Ivoclar acrylic teeth.

MATERIALS AND METHODS

This study compared the bond strength of three types of artificial teeth, including acrylic Ivoclar (Ivoclar Vivadent s.r.l., Casalecchio di Reno, Italy), Apple composite (Ideal Makoo, Makoo, Iran), and B-Star nanocomposite (Ideal Makoo, Makoo, Iran) teeth to acrylic heat-cure denture base resin (Selectaplus H/Trevalon, Dentsply, England). The teeth were compared after the glazed surfaces of the base were removed. Each group of teeth consisted of 18 samples, which were divided into two subgroups (nine samples each). In total, 54 samples were tested. In one of the subgroups, monomer (Selectaplus H/Trevalon, Dentsply, England) was applied on the ridge-lap surface of teeth using a microbrush (Snowdent, Guangdong, China). The monomer was not used in the control group.

This study was conducted in accordance with ISO 10477 standard [18]. Each artificial tooth (premolars and molars) was embedded in a transparent autopolymerized resin (Ortho Resin, Dentsply DeTrey, Konstanz, Germany) such that the ridge-lap surface was outside the resin. Then, 2 mm of the ridge-lap surface from the embedded sample was removed for smoothness using a cutting device (IsoMet

Low-Speed Saw, Buehler, Germany).
In order to control the bonding area, a metal ring with a diameter of 4 mm was fixed on the tooth surface. The ring was filled with melted dental wax (Modeling wax, Red, Cavex, Holland). The mold was removed cautiously after the wax solidified. Next, the samples were horizontally placed inside putty (Speedex; Coltène/Whaledent AG, Altstätten, Switzerland). Half of the wax-transparent acrylic resin was placed inside the putty. Four samples were added to each flask (Fig. 1).

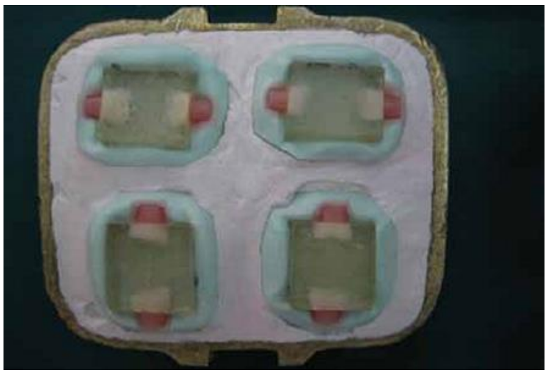

Fig. 1. Arranging the samples in the flask

A dental plaster (Type II Gypsum, Pars Dandan, Tehran, Iran) was first poured into the lower half of the flask. The samples were then embedded in the plaster up to the edge of the putty. Vaseline (Petroleum Jelly, Unilever, Inc., London, UK) was smeared on the plaster and on clear acrylic blocks. Then, putty was placed on the samples, and the upper half of the flask was filled with dental plaster. The flask was placed under pressure (50 kg) for 45 minutes. Afterward, the flask was put in boiling water for one to two minutes until the wax softened. The softened wax was washed with hot water until the bonded surface was completely clean. After drying the hot plaster, the separating agent (MR Dental Biofilm/tin foil substitute, Surrey, UK) was added using a brush. When the flask temperature reached the room temperature, heat-cure resin (Selectaplus H/Trevalon, Dentsply, England) was mixed at a polymer-to-monomer ratio of 2.5:1 (the dough stage) and was packed adjacent to the wax in contact with the teeth. Subsequently, the flask was placed under pressure (100 kg) for 10 minutes and then clamped and cured for eight hours at 74°C as recommended by the manufacturer [19]. After the flask cooled down, the samples were removed and cleaned. The excess acrylic resin was also removed (Fig. 2).

Fig. 2. Samples after removal from putty and cleaning

The samples were kept in distilled water at 37°C [7] and then mounted on a metal holder in a universal testing machine (Model H5KS, Hounsfield Ltd., Surrey, UK).
The blade edge of the device was adjusted exactly at the acrylic resin-tooth interface. A perpendicular load was applied on the acrylic resin and shear force was applied at a cross-head speed of 1 mm/minute until failure. The failure point was recorded by the system's software.
Descriptive statistics, including frequency, mean, and standard deviation (SD), were calculated in SPSS 20 software (SPSS Inc., Chicago, IL, USA). Two-way analysis of variance was used to examine the effect of material type and monomer on bond strength. P-values less than 0.05 were considered statistically significant.

RESUTS

Evaluation of data distribution in all groups using Kolmogorov-Smirnov test showed that data were normally distributed; therefore, parametric tests were used to analyze the data ($P>0.05$).
Table 1 shows the significant effect of material type ($P<0.05$, $f=48.86$), monomer ($P<0.05$, $f=183.91$), and the interaction of material and monomer ($P<0.05, f=28.6$) on bond strength. The results showed that the shear bond strength of nanocomposite artificial teeth to

Table 1: Two-way analysis of variance to investigate the main and mutual effects of material type and monomer

	Sum of squares of the source	Degree of freedom	Mean of squares	F	P-value
Material type	79702.78	2	39851.39	48.86	<0.001
Monomer	149994.74	1	149994.74	183.92	<0.001
Material type Monomer	46659.59	2	23329.80	28.61	<0.001
Error	39146.89	48	815.56		
Total	6125040	54			

Table 2: Comparison of shear bond strength (MPa) of three types of artificial teeth to heat-cure acrylic resin (main effect) with and without monomer (main effect; one-way analysis of variance)

	Material type	No.	Mean	SD	P value
Material type (main effect)	**Acrylic**	18	364.67	39.46	<0.001
	Composite	18	344.39	100.19	
	Nanocomposite	18	274.94	47.7	
Monomer (main effect)	**Without monomer**	27	275.3	53.21	<0.001
	With monomer	27	380.7	59.45	

SD: Standard Deviation

acrylic resin was the lowest, while Ivoclar acrylic teeth showed the highest shear bond strength (P<0.05).

The shear bond strength of composite artificial teeth was significantly lower than that of Ivoclar acrylic teeth and higher than that of nanocomposite teeth. Additionally, the shear bond strength of samples without monomers was significantly lower than that of samples with monomers (Table 2).

Table 3: Comparison of shear bond strength (MPa) of three types of artificial teeth to heat-cure acrylic resin with and without monomer (n=9; interaction effect; one-way analysis of variance).

	Mean	SD	P value
Acrylic without monomer	337.11	32.18	<0.001
Acrylic with monomer	392.22	23.76	
Composite without monomer	250.44	29.84	
Composite with monomer	438.33	24.16	
Nanocomposite without monomer	238.33	27.28	
Nanocomposite with monomer	311.56	32.78	

SD: Standard Deviation

Examination of the interaction of the three tooth types with and without monomers was done by Tukey's post-hoc test (Fig. 3 and Table 3).

The results showed that composite teeth with monomers had the highest shear bond strength among the six groups of samples.

Acrylic Ivoclar teeth with monomers had the second highest shear bond strength; in other words, their bond strength was significantly lower than that of composites with monomers and higher than that of other samples.

The shear bond strengths of Ivoclar acrylic teeth without monomers and nanocomposite teeth with monomers were similar. As the findings revealed, the shear bond strengths of composite and nanocomposite teeth without monomers were similar; these teeth showed the lowest bond strength.

DISCUSSION

Deboning of artificial teeth from the base resin is frustrating for both patients and dentists. As the force on prosthetic components of implants increases, deboning of teeth from the acrylic base of implant-supported prostheses becomes a major clinical problem [20,21]. Today, researchers have found that it is possible to increase the bond strength of artificial teeth to denture bases through

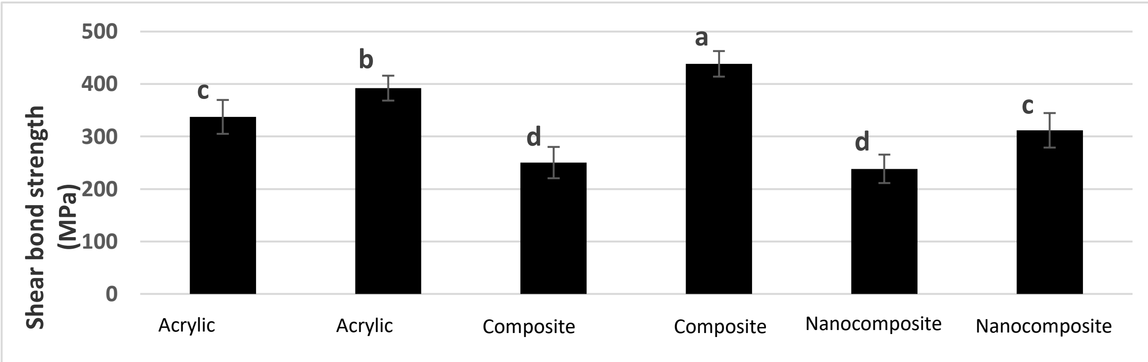

Fig. 3. Shear bond strength (MPa) comparisons of three types of artificial teeth to heat-cure acrylic resin with and without monomer (interaction effect). Columns represent mean values with bars as standard deviation. Letters demonstrate significant differences between the groups as determined by Tukey's test.

physical and chemical changes in the structure of artificial teeth and polymers. Some physical changes include creating very fine holes in the base and in the ridge-lap surface of artificial teeth. The chemical changes include the addition of monomers to the base of teeth before packing acrylic resins, complete removal of wax, rinsing artificial teeth with detergents, changes in the chemical structure of polymers and polymerization reactions [9,22-24], and use of resin cements [9].

This study investigated the effects of monomers on the bond strength of artificial teeth. The results showed that the use of monomers could help increase bond strength. In contrast to these findings, a study by Kawara et al [25] demonstrated that preparation of artificial teeth with monomers does not produce sufficient bond strength. Our results are also not consistent with the findings of studies conducted by Spartley [26] and Barpal et al [24], who found that monomer addition is ineffective. The present findings are also in contrast those reported by Morrow et al [27], who showed that addition of monomers reduced bond strength. Nonetheless, our findings are in line with studies by Yamauchi et al [28], Nejati Danehs et al [29], Papazoglu and Vasilas [17], and Yanikoglu et al [3].

Considering the emergence of new generations of artificial teeth made by domestic companies, such as B-Star nanocomposite artificial teeth and frequent use of Italian Ivoclar artificial teeth in Iran, it is necessary to compare the bond strength of Iranian artificial teeth with that of other brands. The present study showed that the bond strength of Ivoclar acrylic teeth was higher than that of domestic composite and nanocomposite artificial teeth.

Changes in the type of resin base material, the type of artificial teeth, artificial tooth preparation methods, and copolymerization can affect the bond strength [30]. Ghasemi et al [31] investigated the bond strength of several types of multilithic composite artificial teeth (Ivoclar, Yaghut, Glamour, and Apple) to heat-cure resins. The findings showed that the mean bond strength was the highest in the Apple group followed by Yaghut, Glamour, and Ivoclar artificial teeth, respectively. There was a significant difference between some groups, while there was no significant difference between the Glamour and Ivoclar groups [31]. In addition, Naser Khaki and Ehsani [32] compared the bond strength of acrylic artificial teeth (Liechtenstein Ivoclar, Italian Ivoclar, Marjan New, Brilliant, Super Berelian, and Super New Color) to heat-cure acrylic resins and showed that the bond strength of Liechtenstein Ivoclar acrylic artificial teeth was significantly higher than that of other studied artificial teeth. The present results showed that bond strength improves with the addition of monomers. Monomers may cause some porosity and can increase the contact surface area; therefore, greater forces are needed for fracture.

CONCLUSION

Ivoclar acrylic artificial teeth had a significantly higher bond strength compared to composite and nanocomposite artificial teeth, while the difference in bond strength between composite and nanocomposite artificial teeth was not significant. Based on the findings, the addition of monomers to the ridge-lap surface of composite artificial teeth produced greater bond strength compared to the addition of monomers to nanocomposite and acrylic artificial teeth. Composite teeth showed the highest shear bond strength with the addition of monomers.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Huggett R, John G, Jagger RG, Bates JF. Strength of the acrylic denture base tooth bond. Br Dent J. 1982 Sep 7;153(5):187-90.
2. Adeyemi AA, Lyons MF, Cameron DA. The acrylic tooth-denture base bond: effect of mechanical preparation and surface treatment. Eur J Prosthodont Restor Dent. 2007 Sep;15(3):108-14.
3. Yanikoglu DN, Duymus DZ, Bayindir DF. Comparative bond strengths of autopolymerising denture resin and light cured composite resin to denture teeth. Int Dent J. 2002 Feb;52(1):20-4.
4. Vallittu PK, Lassila VP, Lappalainen R. Evaluation of damage to removable dentures in two cities in Finland. Acta Odontol Scand. 1993 Dec;51(6):363-9.
5. Cunningham JL, Benington IC. Bond strength variation of synthetic resin teeth in dentures. Int J Prosthodont. 1995 Jan-Feb;8(1):69-72.
6. Catterlin RK, Plummer KD, Gulley ME. Effect of tinfoil substitute contamination on adhesion of resin denture tooth to its denture base. J Prosthet Dent. 1993 Jan;69(1):57-9.
7. Barbosa DB, Barão VA, Monteiro DR, Compagnoni MA, Marra J. Bond strength of denture teeth to acrylic resin: effect of thermocycling and polymerisation methods. Gerodontology. 2008 Dec;25(4):237-44.
8. Glossary of prosthodontic terms. J Prosthet Dent. 1977;38:66-109.
9. Cunningham JL. Shear bond strength of resin teeth to heat-cured and light-cured denture base resin. J Oral Rehabil. 2000 Apr;27(4):312-6.
10. Büyükyilmaz S, Ruyter IE. The effects of polymerization temperature on the acrylic resin denture base-tooth bond. Int J Prosthodont. 1997 Jan-Feb;10(1):49-54.
11. Thean HP, Chew CL, Goh KI. Shear bond strength of denture teeth to base: a comparative study. Quintessence Int. 1996 Jun;27(6):425-8.
12. Chung RW, Clark RK, Darvell BW. The bonding of cold-cured acrylic resin to acrylic denture teeth. Aust Dent J. 1995 Aug;40(4): 241-5.
13. Matsumura H, Yoshida K, Tanaka T, Atsuta M. Adhesive bonding of titanium with a titanate coupler and 4-META/MMA-TBB opaque resin. J Dent Res. 1990 Sep;69(9): 1614-6.
14. Takahashi Y, Chai J, Takahashi T, Habu T. Bond strength of denture teeth to denture base resins. Int J Prosthodont. 2000 Jan-Feb;13(1):59-65.
15. Ghahramani L, Shahabi S, Amirjan A, Fazel A. Comparison of bond strength of composite and acrylic teeth to heat-cured and auto-polymerized acrylic denture base. J Dent Med Tehran Univ Med Sci. 2010;23(4):215-226.
16. Chittaranjan B, Taruna M, Sudheer N, Patil NS. Evaluation of shear bond strength of three different types of artificial teeth to heat cure denture base resin: an in vitro study. Indian J Dent Res. 2013 May-Jun;24(3):321-5.
17. Papazoglou E, Vasilas AI. Shear bond strengths for composite and autopolymerized acrylic resins bonded to acrylic resin denture teeth. J Prosthet Dent. 1999 Nov;82(5):573-8.
18. INTERNATIONAL STANDARD. ISO 10477 Second edition 2004-10-01. Dentistry — Polymer-based crown and bridge materials. ISO 10477:2004(E). Available at: http://matsec.ustb.edu.cn/downloadpdf.do?path=bioevaluationstandard&filename=ISO%2010477-2004.pdf/ Accessed April 12, 2018.

19. Nematollahi F, Azizi N, Shahabi S, Ghahremani L, Asgari Z, Bagheri H. Comparison effect of artificial tooth type and cyclic loading on the bond strength to auto-polymerized acrylic denture base resins. J Dent Med Tehran Univ Med Sci. 2013 Sep;26(2):81-90.
20. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants. 1991 Fall;6(3):270-6.
21. Cunningham JL, Benington IC. Effect of an experimental cement on denture tooth bond. J Dent Res. 1994:74:949.
22. Baghani MT, Yahyazadehfar N, Zamanian A, Abbasi K, Shanei F, Shidfar S, et al. Factors Affecting Bonding Strength of Artificial Teeth: A Literature Review. J Res Med Dent Sci. 2018 Feb;6(1):184-191.
23. Caswell CW, Norling BK. Comparative study of the bond strengths of three abrasion-resistant plastic denture teeth bonded to a cross-linked and a grafted, cross-linked denture base material. J Prosthet Dent. 1986 Jun;55(6):701-8.
24. Barpal D, Curtis DA, Finzen F, Perry J, Gansky SA. Failure load of acrylic resin denture teeth bonded to high impact acrylic resins. J Prosthet Dent. 1998 Dec;80(6):666-71.
25. Kawara M, Carter JM, Ogle RE, Johnson RR. Bonding of plastic teeth to denture base resins. J Prosthet Dent. 1991 Oct;66(4):566-71.
26. Spratley MH. An investigation of the adhesion of acrylic resin teeth to dentures. J Prosthet Dent. 1987 Sep;58(3):389-92.
27. Morrow RM, Matvias FM, Windeler AS, Fuchs RJ. Bonding of plastic teeth to two heat-curing denture base resins. J Prosthet Dent. 1978 May;39(5):565-8.
28. Yamauchi M, Iwahori M, Sakai M, Koda T, Kawano J, Maeno T. Comparative bond strengths of plastic teeth to microwave-curing, heat-curing and 4-META containing denture base resins. Gifu Shika Gakkai Zasshi. 1989 Dec;16(2):542-50.
29. Nejati Danehs F, Savabi O, Salehi M. The comparative study of different methods in increasing bonding strength of plastic teeth to acrylic resin base. J Dent Sch Shahid Beheshti Univ Med Sci. 2004 Winter;21(4):584-590.
30. Harrison A, Huggett R. Effect of the curing cycle on residual monomer levels of acrylic resin denture base polymers. J Dent. 1992 Dec;20(6):370-374.
31. Ghasemi E, Mosharraf R, Eidi Najafabadi A. Evaluation of bond strength of four types of multilithic teeth to acrylic denture base material. J Islam Dent Assoc Iran (JIDAI). 2011 Winter;22(4):240-247.
32. Naser Khaki M, Ehsani S. Comparing the bond strength of four kinds of Ideal-Makoo artificial teeth (Iran) and two Liechtenstein and Italy Ivoclar teeth with prosthetic acrylic base. J Dent Sch Shahid Beheshti Univ Med Sci. 2007 Autumn;25(3):310-15.