Atatürk Üniv.Diş Hek.Fak.Derg.
Cilt:14, Sayı 3, Sayfa: 9-16 , 2004

THE EVALUATION OF THE EFFECTS OF VARIOUS SURFACE TREATMENTS ON BOND STRENGTH OF ARTIFICIAL TEETH TO DENTURE BASE RESIN

Asude YILMAZ*, DDS, PhD **Yücel YILMAZ**, DDS, PhD**

ABSTRACT

The aim of this study was to compare the bond strength of acrylic resin teeth treated in various ways to heat-cured acrylic base resin material. A total of 64 cylindrical wax specimens with 20mm in length and 9mm in diameter were produced and they were reduced to 7 mm diameter in order that a butt-joint existed at the interface of acrylic denture base resin and artificial tooth. Sixty-four acrylic resin artificial teeth were inserted into the center of these cylindrical wax specimens as their incisal edges parallel to the floor and their long axis vertical to the floor. Specimens were then divided randomly into 4 groups containing equal number of specimens. Subsequently, all samples were flasked. The ridge lap surfaces of acrylic teeth were painted with the methyl methacrylate monomer (MMA) in Group 2, with a bonding agent in Group 3, and both with MMA and bonding agent in Group 4 before packing the acrylic base resin material. In Group 1, no surface treatment was applied and this group was used as the control group. One sample from each group was excluded to inspect the interface between the acrylic base material and acrylic tooth interface under Scanning Electron Microscope. Remaining specimens were compressively loaded under 135° angle and 1.5 mm/min crosshead speed until failure. The data obtained were analyzed statistically using one way ANOVA test. ANOVA reveals statistically significant differences between the groups (P<0.000). Post-Hoc multiple comparisons were made with Tukey's test. Tukey's multiple comparisons reveal a significant increase in acrylic tooth bond strength in comparison with the control group. It is recommended that different surface treatments on the ridge lap surfaces of acrylic teeth before packing acrylic base material were found helpful to maintain a reliable bond between the acrylic teeth and the acrylic resin base material.

Key Words: Acrylic resin teeth, bond strength, ridge lap surface treatment

FARKLI YÜZEY İŞLEMLERİNİN AKRİLİK YAPAY DİŞLERİN AKRİLİK REZİN KAİDE MATERYALİNE BAĞLANMA DAYANIMI ÜZERİNE ETKİSİNİN DENEYSEL OLARAK İNCELENMESİ

ÖZET

Bu çalışmanın amacı, çeşitli yüzey işlemleri uygulanmış akrilik rezin dişlerin ısı ile polimerize olan akrilik rezin kaide materyaline bağlanma dayanımını değerlendirmektir. Bu amaçla; 9mm çapında ve 20mm boyunda 64 adet silindirik mum örnek hazırlanmış ve akrilik kaide rezini ile diş yüzeyinin devamlılık sağlayacak şekilde birleşimini sağlamak için örnek çapı 7mm' ye düşürülmüştür. Örnekler, rastlantısal yolla her biri eşit sayıda örnek içeren 4 gruba ayrılmıştır (n=16). Daha sonra örnekler muflalanmıştır. Akrilik rezin dişlerin bağlanma yüzeyleri Grup 2' de metilmetakrilat (MMA) monomeri ile, Grup 3' te bağlayıcı ajan ile ve Grup 4' te MMA ve bağlayıcı ajan ile akrilik tepme işleminden önce işlemlenmiştir. Grup 1' deki örneklere hiçbir uygulama yapılmamıştır ve bunlar kontrol olarak kullanılmıştır. Her bir gruptan bir örnek, akrilik rezin kaide materyali-akrilik diş ara yüzünün mikroskobik değerlendirmesi için ayrılmıştır. Mikroskobik değerlendirme için, Taramalı Elektron Mikroskobu' ndan (SEM) yararlanılmıştır. Örneklere; 135°' lik açı ile 1,5 mm/dak. başlık hızında, kırılma gerçekleşene kadar kuvvet uygulanmıştır. Tek yönlü varyans analizi, gruplar arasında istatistiksel olarak anlamlı farklılık bulunduğunu göstermiştir (P< 0,000). Gruplar arasındaki farklılığın kaynağını göstermek için uygulanan Tukey HSD çoklu karşılaştırma testi ise; yüzey işlemi uygulanmış akrilik rezin dişlerin uygulanmamış olan dişlerden daha fazla bağlanma dayanımına sahip olduklarını göstermiştir. Akrilik tepme işleminden önce akrilik rezin dişlerin bağlanma yüzeylerinin işlemlenmesinin yararlı olduğu görülmüştür.

Anahtar Kelimeler: Akrilik rezin dişler, bağlanma dayanımı, yüzey işlemleri.

TDB 9. Bilimsel Kongresi' nde sözlü bildiri olarak sunulmuştur (İzmir-2002).
* Department of Prosthetic Dentistry, Atatürk University, Faculty of Dentistry, Erzurum-Turkey.
** Department of Pedodontics, Atatürk University, Faculty of Dentistry, Erzurum-Turkey.

INTRODUCTION

It was stated that the repairs applied to acrylic dentures due to failures were originated from either fracture of the acrylic base or debonding of the artificial teeth from the base.[8] Huggett et al.[11] determined that 22 % and 30 % of denture repairs involve tooth debonding in the anterior region of the denture. In order to solve this problem, various chemical procedures such as wetting the ridge lap of an acrylic resin tooth with methyl methacrylate (MMA) monomer, mixture of monomer-polymer, dichloromethane (CH_2Cl_2), trichloromethane (chloroform $CHCl_3$), bonding agent and their combination as well as some mechanical procedures such as grinding the ridge lap surfaces and preparing retention grooves on the surfaces were applied.[3-6,9,12-14,17-19,21,23]

MMA monomer applications to increase bonding of other polymeric materials to acrylic tooth ridge lap surfaces either compromised or had no effect on the bond strength.[1,17] Vallittu et al.[20] emphasised, in order to form a strong bond between denture base resin and artificial tooth, that there should be three minutes wetting time of ridge lap surface of the latter with MMA monomers.

Chai et al.[6] explained that applying of CH_2Cl_2 to the traditional and high cross-linked acrylic teeth increases to bonding strength significantly.However, Rupp et al.[14] stated that CH_2Cl_2, a nonpolymerizable solvent, as a solvent will remove natural oil from the skin and therefore, frequent contact should be avoided. Furthermore, care should be taken to avoid inhaling during treating of ridge lap surface of artificial tooth with chloroform[16] because it may be a carcinogen.[2]

Cunningham and Benington[9] compared the samples on which they made no surface treatment with a commercial cement and an experimental cement application in their study in which they investigated to bonding between the acrylic resin teeth and denture base resin. They found that the application of cements was produced the most significant increase in acrylic tooth bond strength.

Suzuki et al.[18] found that the application of 4-META adhesive agent, an ingredient of fourth-generation bonding agents[7], to highly cross-linked teeth prior to packing of the resin dough significantly improved the bonding. However, no research related bonding agents included bis-GMA, fifth-generation bonding agents, has been published.

The purpose of this study was to investigate the bond strengths of cross-linked acrylic resin teeth to acrylic resin denture base material after the applying of MMA monomer, bonding agent, and MMA-bonding agent.

MATERIALS AND METHODS

In this study, 64 cylinders of set-up modelling wax (DeTrey- Dentsply, Bois Colombes, France) 9 mm in diameter and 20 mm in length were prepared to use in preparation of the specimens. Then, one side of each specimens were reduced to 7 mm in diameter by using a modelling spatula so that a butt joint existed at the interface of polymethyl methacrylate (PMMA) acrylic resin denture base material (QC-20, DeTrey-Dentsply, Milford, U.K.) and acrylic teeth.[8] According to the ADA Specification No.15, cross-linked acrylic resin teeth bigger than 8 mm in diameter were chosen

and their diameters were reduced to 8 mm by cutting into shape with a steel fissure bur (Dentsply, #60-L, USA). The teeth, maxillary central incisors (Majordent, Moncalieri, Italy), were inserted into the centre of the cylindrical wax specimens as their incisal edges parallel to the floor and their long axes vertical to the floor (Fig.1).

64 specimens were fabricated and they were divided into four groups of equal number and flasked. Then, the wax was eliminated with running hot water.

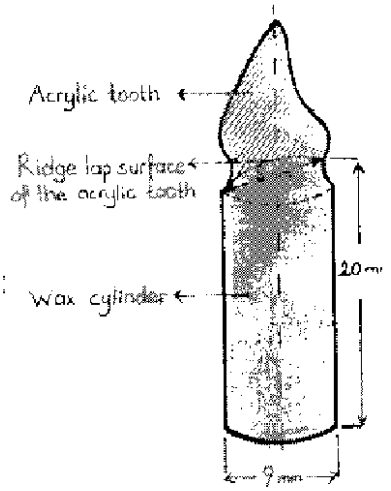

Fig. 1. Sample assembly

Surface treatment methods which applied to the specimen groups as follows:

Group 1: This group was used as control group. No further application of the ridge lap surface of the teeth was carried out.

Group 2: The ridge lap surfaces of teeth were painted with MMA monomer (QC-20, DeTrey- Dentsply, Milford, U.K.) for 180-second at room temperature before packing PMMA denture base resin.[20]

Group 3: Bonding agent (Single Bond, 3M Dental Products St.Paul, MN, USA) included bis-GMA, HEMA, dimethacrylates, ethanol, water, and photoinitator was applied to the ridge lap surfaces of teeth for 25-second and then cured using visible light for 10-second.

Group 4: The ridge lap surfaces of teeth were painted with MMA monomer for 180-second at room temperature. Subsequently, bonding agent was applied to the same surfaces for 25-second and then cured using visible light for 10-second.

The liquid/powder ratio of QC acrylic resin (QC-20, DeTrey-Dentsply, Milford, U.K.) was balanced as 1.0ml of liquid to 2.3 g of powder. PMMA denture base resin was packed in the flask and cured by boiling according to the manufacturer's instructions. The specimens were deflasked upon the completion of heat curing process and excess resin was removed on the specimens by using Sof-Lex contouring and polishing disks (3M-ESPE, Seefeld, Germany). Then, all specimens were stored at room temperature for 24 hours in distilled water.

Except for one sample from each group, all samples were tested with a mechanical testing machine (Hounsfield Test Equipment, Roydan, England). The load was applied using a stainless steel pin, similar to knife edge, with a sampler holder at 45 degrees from the long axis of each acrylic tooth at a cross head speed of 1.5 mm/min on the palatal surface until failure occurred (Fig. 2). The values of forces required to separate the acrylic resin teeth from the denture base resin were recorded in Newton (N). The loads (N) that caused failure of the samples were converted to megapascals as follows:

$MPa = Newtons/mm^2$

The data obtained were analyzed using one way ANOVA. When the F ratio was significant, Tukey's multiple comparison test was used to compare means.

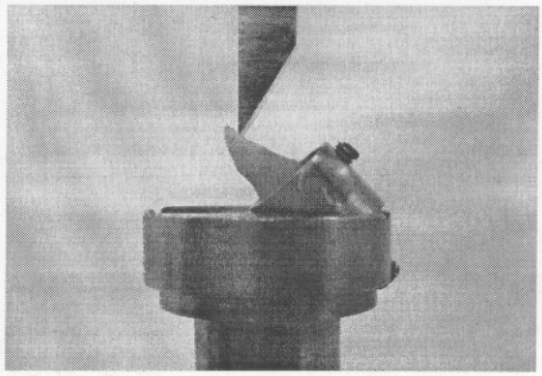

Fig. 2. Specimen tested in testing machine.

For all specimens, the interface where failure occurred was visually inspected. The failure was determined as either adhesive or cohesive in nature. Failure modes data were statistically analyzed with Kruskall-Wallis methods.

Four samples, without being subjected to compressive load test, were cut in such a way as to be longitudinal of the acrylic tooth in the buccolingual direction. Interface acrylic resin tooth-denture base resin was evaluated. The thickness of sputtered gold on the sample surface was 70 nm. Samples were examined in the SEM (Jeol-6400 Scanning Electron Microscope, Osaka, Japan) at 7-10 kV accelerating potential. SEM photomicrographs were taken.

RESULTS

The mean values for the fracture strength of groups 1 through 4 varied from 33.633 to 45.670 MPa (Table 1). One way ANOVA was revealed significant differences among groups with respect to bond strength ($P<0.000$). According to Tukey's test (Table 1): the fourth group had significantly higher mean bond strength than groups 1 and 3 ($P<0.05$): the first group had significantly lower mean bond strength than the other groups ($P<0.05$): no statistically significant differences ($P>0.05$) in bond strength were noted between groups 2 and 3 and groups 2 and 4.

Table 1. The mean values, standard deviations and Tukey's multiple range comparison results (MPa).

Groups	n	Mean	SD
Control	15	33.633^{a}	4.671
MMA	15	$42.928^{b,c}$	3.499
Adhesive	15	39.385^{b}	5.078
MMA-Adhesive	15	45.670^{c}	3.672

Values designated with the same superscript letter are statistically insignificant ($P>0.05$).

Failures occurred in all specimens were examined visually (adhesive and cohesive) and results were shown in Table 2. Kruskall-Wallis analysis of variance was used to determine whether there was any significant difference between the failure types in all groups and it was found that the differences were insignificant ($P>0.05$). The percentage of adhesive failures decreased from 66.6% to 33.4% (Table 2).

Table 2. Failure modes and occurences

Groups	Adhesive failures (%)	Cohesive failures (%)
Control	10 (66.6)	5 (33.4)
MMA	7 (46.6)	8 (53.4)
Adhesive	9 (60)	6 (40)
MMA-Adhesive	5 (33.4)	10. (66.6)

SEM photomicrographs of interfaces of treated acrylic resin teeth with different agents to denture base resin demonstrated a zone, swelled layer, with different thickness (Figs. 4-6). However, this zone was not obviously observed in control group (Fig. 3).

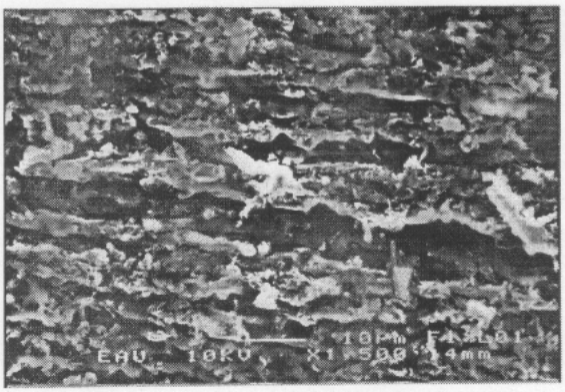

Fig. 3. SEM micrograph of the control specimen (original magnification x1500).

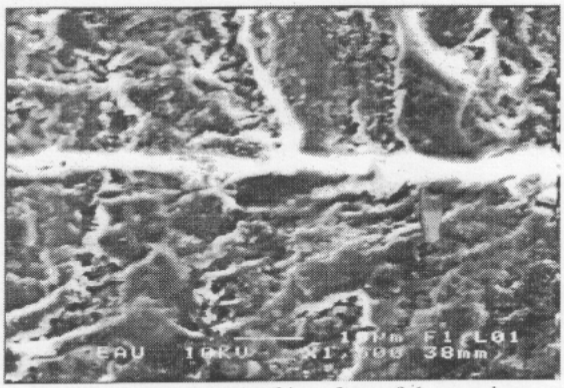

Fig. 4. SEM micrograph of interface of denture base resin and acrylic resin tooth after MMA treatment (original magnification x1500).

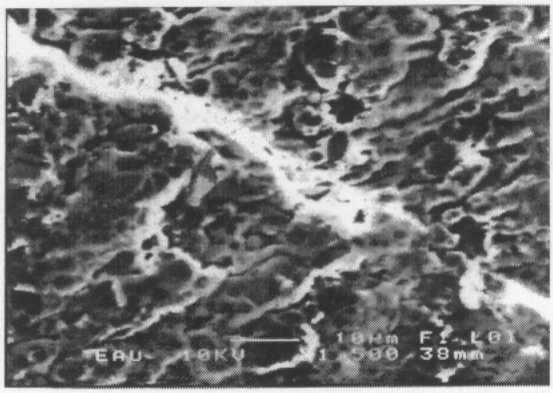

Fig. 5. SEM micrograph of interface of denture base resin and acrylic resin tooth after bonding agent treatment (original magnification x1500).

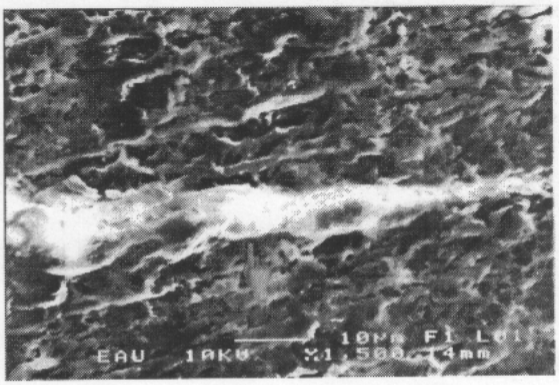

Fig. 6. SEM micrograph of interface of denture base resin and acrylic resin tooth after MMA + bonding agent treatments (original magnification x1500).

DISCUSSION

The acrylic resin artificial teeth are often preferred because of their chemical bonding to denture base materials. However, it was pointed out that debonding from denture base material of artificial teeth was occurred, especially upper denture.[13,15,17]

Acrylic resin teeth are composed of PMMA polymer beads embedded in a matrix of cross-linked PMMA. It was pointed out that monomers emanating from the polymerizing denture resin penetrate the artificial tooth resin

and swelling its surface, and this swelling is a result of the reaction of the monomer with the polymer beads of PMMA matrix.[6,14,19] The bond strength obtained from the control group may be explained to this type reaction. It was stated that the joint surface of an acrylic resin tooth must be adequately dissolved.[21] In present study, the use of MMA monomer on ridge lap surface of artificial tooth before the acrylic resin dough was packed produced higher bond strength in comparison with control group ($P<0.05$). This indicated that the use of MMA monomer is softening the acrylic resin tooth. In this study, the ridge lap surfaces of acrylic teeth were treated with MMA monomers for 180-second. Wetting the heat polymerized acrylic resin surfaces with MMA for 180-second has been suggested to dissolves the poly(methyl methacrylate).[20]

Although group 2 (use of bonding agent only) possessed slightly lower bond strength than group 3, none of the differences was statistically significant ($P>0.05$). This situation may dependent on poorer wettability properties of the bonding agent than MMA monomer.[20]

In present study, bonding agent application (group 3) gave higher mean average values when compared with the control group (group 1). This may depend on the dissolving effect of adhesive agent composed of a solvent.[10] The strength of the bond is dependent on the degree of penetration of the solvent.[14]

MMA-bonding agent combination (group 4) applied on the ridge lap surface of the acrylic teeth provided better bonding than other groups. This finding was in accordance with the result of Suzuki et al.[18] They found that the application of 4-META adhesive agent, coupled to MMA monomer, to denture teeth improved the bonding between denture teeth and denture base material.

In our study, although visual examination of the failure mode of artificial teeth in chemically prepared groups possessed less the number of adhesive failures than teeth in control group, none of the differences was statistically significant ($P>0.05$). The adhesive failure of artificial teeth to control group, MMA group, bonding agent group, and MMA-bonding agent group was 66.6%, 46.6%, 60%, and 33.4%, respectively. These may remind the fact that surface treatments (in groups 2, 3, and 4) increases the wettability of the ridge lap surface of acrylic resin teeth.[10] The number of adhesive failure types was diminished.

The results of bond strength together with and visual examination of the failure mode showed that bonding between artificial tooth and denture base resin was improved when the ridge lap surface of artificial tooth was well dissolved with MMA monomer, bonding agent, or MMA-bonding agent applications.[20]

SEM views between the denture base material and artificial tooth interfaces, revealed a diffusion zone (Figs. 4, 5, and 6). Vallittu and Ruyter[22] stated that the thickness of the swelled layer is related to the bond strength between denture base resin material and artificial tooth. This may be attributed to higher mean bond strength values between denture base material and acrylic tooth when compared with control group.

CONCLUSION

The influence of MMA, bonding agent, and MMA-bonding agent applications on ridge lap surface of the acrylic denture teeth improved the bond strength.

REFERENCES

1. Barpal, D., Curtis, D.A., Finzen, F., Perry, J. and Gansky, S.A.: Failure load of acrylic resin denture teeth bonded to high impact acrylic resins. J Prosthet Dent 80 : 666-671, 1998.

2. Budavari, S.: The Merck Index. Whitehouse Station, NJ:Merck,1996.

3. Cardash, H.S., Liberman, R. and Helft, M.: The effect of retention grooves in acrylic resin teeth on tooth-denture base bond. J Prosthet Dent 55 : 526-528, 1986.

4. Cardash, H.S., Applebaum, B., Baharav, H. and Liberman, R.: Effect of retention grooves on tooth-denture base bond. J Prosthet Dent 64 : 492-496, 1990.

5. Catterlin, R.K., Plummer, K.D. and Gulley, M.E.: Effect of tinfoil substitute contamination on adhesion of resin denture tooth to its denture base. J Prosthet Dent 69 : 57-59, 1993.

6. Chai, J., Takahashi, Y., Takahashi, T. and Habu, T.: Bonding durability of conventional resinous denture teeth and highly crosslinked denture teeth to a pour-type denture resin. Int J Prosthodont 13 : 112-116, 2000.

7. Craig, R.G. and Powers, J.M.: Restorative dental materials, 11th ed., Mosby Inc., St Louis, 2002, pp.259-286.

8. Cunningham, J.L.: Bond strength of denture teeth to acrylic bases. J Dent 21 : 274-280, 1993.

9. Cunningham, J.L. and Benington, I.C.: An investigation of the variables which may affect the bond between plastic teeth and denture base resin. J Dent 27 : 129-135, 1999.

10. Cunningham, J.L.: Shear bond strength of resin teeth to heat-cured and light-cured denture base resin. J Oral Rehabil 27 : 312-316, 2000.

11. Huggett, R., John, G., Jagger, R.G. and Bates, J.F.: Strength of the acrylic denture base tooth bond. Br Dent J 153 : 187-190, 1982.

12. Kawara, M., Carter, J.M., Ogle, R.E. and Johnson, R.R.: Bonding of plastic teeth to denture base resins. J Prosthet Dent 66 : 566-571, 1991.

13. Morrow, R.M., Matvias, F.M., Windeler, A.S. and Fuchs, R.S.: Bonding of plastic teeth to two heat-curing denture base resins. J Prosthet Dent 39 : 565-568, 1978.

14. Rupp, N.W., Bowen, R.L. and Paffenbarger, G.C.: Bonding cold-curing denture base acrylic resin to acrylic resin teeth. J Am Dent Assoc 83 : 601-606, 1971.

15. Schoonover, I.C., Fisher, T.E., Serio, A.F. and Sweeney, W.T.: Bonding of plastic teeth to heat cured denture base resins. J Am Dent Assoc 44 : 285-287, 1952.

16. Shen, C., Colaizzi, F.A. and Birns, B.: Strength of denture repairs as influenced by surface treatment. J Prosthet Dent 52 : 844-848, 1984.

17. Spratley, M.H.: An investigation of the adhesion of acrylic resin teeth to dentures. J Prosthet Dent 58 : 389-392, 1987.

18. Suzuki, S., Sakoh, M. and Shiba, A.: Adhesive bonding of denture base resins to plastic denture teeth. J Biomed Mater Res 24 : 1091-1103, 1990.

19. Takahashi, Y., Chai, J., Takahashi T. and Habu, T.: Bond strength of denture teeth to denture base resins. Int J Prosthodont 13 : 59-65, 2000.

20. Vallittu, P.K., Lassila, V.P. and Lappalainen, R.: Wetting the repair surface with methyl methacrylate affects the transverse strength of repaired heat-polymerized resin. J Prosthet Dent 72 : 639-643, 1994.

21. Vallittu, P.K.: Bonding of resin teeth to the polymethyl methacrylate denture base material. Acta Odontol Scand 53 : 99-104, 1995.

22. Vallittu, P.K. and Ruyter, I.E.: The swelling phenomenon of acrylic resin polymer teeth at the interface with denture base polymer. J Prosthet Dent 78 : 194-199, 1997.

23. Yesil, Z. and Yilmaz, A.: An investigation of the bond strength of plastic teeth to heat-cured denture base resins. Ege Univ Dis Hek Fak Derg 20 : 1-7, 1999. (in Turkish)

Yazışma Adresi
Yrd. Doç. Dr. Asude YILMAZ
Atatürk Üniversitesi
Diş Hekimliği Fakültesi
Protetik Diş Tedavisi Anabilim Dalı
ERZURUM