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 20 mm in length and 9 mm in diameter were produced and they were reduced to 7 mm 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 specimens were finished. 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 133° 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 teeth 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 AKRILİK YAPAY DIŞLERİN AKRILİK REZİN KAİDE MATERYALIŅE BAĞLANMA DAYANIMI ÜZERİNE ETİKİSİNİN DENEKSEL OLARAK İNCELENMESİ

ÖZET

Bu çalışmamın amaç, çeşitli yüzey işlemleri uygulanan akrilik rezin dişlerinin倒塌 ile polimizere olan akrilik rezin kaide materyalinin dayanımı değişiminin degerlendirilmesini, bu amaçla, 9 mm çapında ve 20 mm boyunda 64 adet silindirik numa ömek hazırlanan ve akrilik kaide rezin ile diş yüzeyinin devamlılığı sağlayacak şekilde birleştirilmişi saflak için ömek çap 7 mm’ye değiştirilmiştir. Örneklere, nisbeten yolla hıç biri eşit sayıda ömek ören 4 gruba ayrılmıştır (n=16). Daha sonra örneklere mutfurlandırılmıştır. Akrilik rezin dişlerin bağlanma yüzeyleri Grup 2’de metilmetakrilat (MMA) monomeri ile, Grup 3’te bağlanma ajan ile ve Grup 4’te MMA ve bağlanma ajan ile akrilik tepme işleminden önce işlenmiştir. Grup 1’deki örneklere hiçbir uygulama yapılmamıştır ve bandır kontrol olarak kullanılmıştır. Her bir grupta bir örnek, akrilik rezin kaide materyali-akrilik diş ana yüzünü mikroskopik değerlendirmesi için ayrılmıştır. Mikroskopik değerlendirmeye için, Tarih Elektron Mikroskopu’ndan (SEM) yarantılımıdır. Örneklere; 150° lik açı ile 1.5 mm/min hızda atık hizada, kırılma gerkeşeğine kadar kurvvet uygulanmıştır. Tek yönlü varyans analizi, gruplar arasında istatistiksel olarak anlamlandırılmıştır (İ<0.000). Gruplar arasındaki farklilikın kaynakını göstermek için uygulanan Tukey HSD çoklu karşılaştırma testi ise; yüzey işlemi uygulanan akrilik rezin dişlerin uygulandığını ön dişlerden daha fazla bağlanma dayanımı sağlarken göstermiştir. Akrilik tepme işleminden önce akrilik rezin dişlerin bağlanma yüzeylerinin işlenmesi, yarart olduğu görülmüştür.

Anahtar Kelimeler: Akrilik rezin dişler, bağlanma dayanımı, yüzey işlemleri.
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. Huggett et al. 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 (CH₂Cl₂), trichloromethane (chloroform CHCl₃), 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. 

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. Vallittu et al. 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. explained that applying of CH₂Cl₂ to the traditional and high cross-linked acrylic teeth increases to bonding strength significantly. However, Rupp et al. stated that CH₂Cl₂, 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 because it may be a carcinogen.

Cunningham and Benington 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. found that the application of 4-META adhesive agent, an ingredient of fourth-generation bonding agents, 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. 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 flanked. Then, the wax was eliminated with running hot water.

![Acrylic tooth](image)

**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 photoinitiator 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, Roydland, 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:

\[
\text{MPa} = \frac{\text{Newtons}}{\text{mm}^2}
\]
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 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>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>15</td>
<td>33.633b</td>
<td>4.671</td>
</tr>
<tr>
<td>MMA</td>
<td>15</td>
<td>42.928b,c</td>
<td>3.499</td>
</tr>
<tr>
<td>Adhesive</td>
<td>15</td>
<td>39.383b</td>
<td>5.078</td>
</tr>
<tr>
<td>MMA-Adhesive</td>
<td>15</td>
<td>45.670b</td>
<td>3.672</td>
</tr>
</tbody>
</table>

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 occurrences

<table>
<thead>
<tr>
<th>Groups</th>
<th>Adhesive failures (%)</th>
<th>Cohesive failures (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10 (66.6)</td>
<td>5 (33.4)</td>
</tr>
<tr>
<td>MMA</td>
<td>7 (46.6)</td>
<td>8 (53.4)</td>
</tr>
<tr>
<td>Adhesive</td>
<td>9 (60)</td>
<td>6 (40)</td>
</tr>
<tr>
<td>MMA-Adhesive</td>
<td>5 (33.4)</td>
<td>10 (66.6)</td>
</tr>
</tbody>
</table>

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).

**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.\textsuperscript{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.\textsuperscript{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).\textsuperscript{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.\textsuperscript{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.\textsuperscript{10} The strength of the bond is dependent on the degree of penetration of the solvent.\textsuperscript{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.\textsuperscript{28} 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.\textsuperscript{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.\textsuperscript{20} SEM views between the denture base material and artificial tooth interfaces, revealed a diffusion zone (Figs. 4, 5, and 6). Vallittu and Ruyter\textsuperscript{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.
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Yazışma Adresi
Yrd. Doç. Dr. Asude YILMAZ
Atatürk Üniversitesi
Diş Hekimliği Fakültesi
Prostetik Diş Tedavisi Anabilim Dalı
ERZURUM

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