STRENGTH COMPARISON OF DIFFERENT REPAIR MATERIALS AFTER ATTACHMENT PICK-UP: AN IN VITRO STUDY

by

KARLA BELONIA DOMINGO

MICHAEL MCCracken, Committee Chair
JOHN BURGESS
AMJAD JAVED
MARK Litaker

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KARLA BELONIA DOMINGO

CLINICAL DENTISTRY

ABSTRACT

Statement of the Problem: Implant overdentures become thinner and weaker after picking up attachment housings. While much has been done to examine denture repair methods, these data do not directly apply to attachment pick-up, because the introduction of a metal housing into the acrylic base changes the dynamic of the repair. It is clinically desirable to make as strong a construct as possible to avoid overdenture fracture.

Purpose: This study compared the fracture strength of 4 different repair materials for chair-side attachment pick-up: self-cured acrylic, light-cured acrylic, self-cured with silanated attachment housing and light-cured acrylic with silanated attachment housing.

Materials and Methods: Eighty 11.5x9.1x39 mm heat-cured acrylic blocks were processed, assessed for porosities and finished with increasing grit sandpaper. An 8.5 mm diameter hole was drilled to a depth of 5 mm in the center of each block. Titanium alloy attachment housings were set into the bases using 4 different repair materials: self-cured, light-cured, self-cured with silanated attachment housing and light-cured acrylic with silanated attachment housing. Housings were silanated using the Rocatec system. All acrylic blocks were immersed in water for 30 days for saturation in an incubation chamber. A 3-point bend test was done using a universal testing machine. The force to failure for each specimen was measured. Results were compared using ANOVA with alpha=0.05.

Results: Self-cure acrylic with silanated attachment housings had the highest mean
flexural strength (863.1 N). A comparison among the four groups showed that there were significant differences in flexural strength (p<0.0001) between the silanated and non-silanated self-cured acrylic groups but not between the light-cured acrylic groups.

**Conclusion:** The flexural strength of self-cured acrylic with silanated attachment housings was significantly higher than self-cured, light-cured, and light-cured with silanated attachment housing groups.

**Clinical Implications:**

These data suggest clinicians should use self-cured acrylic resin to do chairside attachment pick-up. Strength can also be improved if housings are silanated.
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TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Denture Base Materials</td>
<td>1</td>
</tr>
<tr>
<td>Overdentures</td>
<td>2</td>
</tr>
<tr>
<td>Repair Materials</td>
<td>3</td>
</tr>
<tr>
<td>Silanation</td>
<td>6</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>8</td>
</tr>
<tr>
<td>RESULTS</td>
<td>14</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>21</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>25</td>
</tr>
<tr>
<td>RECOMMENDATION</td>
<td>26</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>27</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
</tr>
</tbody>
</table>

1. Tukey's test (Dependent Variable: Flexural Load)
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean flexural strength of 4 repair methods</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>Mean flexural strength showing the interaction between the 2 effects: silanation vs repair material type</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Fracture Sites</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Self-cured acrylic group</td>
<td>17</td>
</tr>
<tr>
<td>B</td>
<td>Light-cured acrylic group</td>
<td>18</td>
</tr>
<tr>
<td>C</td>
<td>Self-cured acrylic with silanated attachment housing group</td>
<td>19</td>
</tr>
<tr>
<td>D</td>
<td>Light-cured acrylic with silanated attachment housing group</td>
<td>20</td>
</tr>
</tbody>
</table>
INTRODUCTION

Implant overdentures have become the standard of care for edentulous patients. One of the favored treatments is to pick up implant attachment housings into the denture using chairside techniques with self-cured repair resin. The attachment housings on the denture will then snap on to the implant abutments and help with the retention of the prosthesis. The denture has to be relieved to provide enough space to accommodate these housings, resulting in a thin denture base. A lot of research has been done regarding denture base repair methods. However, these data do not directly apply to repairs involving attachment pick-up. Repair of implant overdentures for attachment housing pick-up does not only entail optimal bonding of the denture base resin and the repair material but also the adhesion between the repair material and the attachment housing. The introduction of the metal housing greatly changes the dynamic of the repair thus it is desirable for patient care to use the strongest method available to pick-up attachments. One particularly interesting area of this research examines the use of silane coupling agents on the metal surface of the attachment housing. This could possibly be an easy and cost-effective way to improve the strength of the denture after attachment pick-up.

Denture Base Materials. The most commonly used material for denture fabrication is polymethyl methacrylate\(^1\) (PMMA), which is the usual constituent of acrylic resins\(^2\). Acrylic resins are used in dental practice mainly in fabrication of
complete or removable partial dentures, transitional prostheses, and implant-supported prostheses. In the early 1980s, light-cured denture base resin was introduced to the market. It was considered an alternative to heat and self-cured polymethyl methacrylate due to its lack of methylmethacrylate monomer, thus eliminating contact allergies and laboratory vapors. Light-activated Urethane Dimethacrylate (UDMA) resins were also developed to eliminate traditional and lengthy flasking processes involved with the use of PMMA based materials. In a study done by Ali et al., comparing heat-only curing and self-curing denture base polymers (p<0.05) with light- and heat-cured UDMA denture base polymer, the latter resulted in a statistically greater values of surface hardness, flexural strength, and flexural modulus. The study showed higher surface hardness (18.02±0.99 VHN) for Triad (UDMA-based) than PMMA denture resin (17.08± 0.49 VHN) and this was congruent with the study done by Khan et al in 1987. However, due to physical and esthetic properties, availability, reasonable cost and ease of manipulation, PMMA resins have been preferred as denture base resins. PMMA-based acrylic resins can be heat-activated, or chemically-activated, also known as self-curing acrylic. Modifications of the physical and chemical properties of resins have been done to aid the processing of removable partial and complete dentures. Cross-linking agents such as glycol dimethacrylate and rubber or fibers are added resulting in improvement of toughness, impact resistance as well as prevention of crack propagation.

**Ondentures.** Patients who received implant-supported dentures reported improved function and satisfaction, showing a diet with more fiber. However, this may also suggest an increase in forces generated with masticatory function. Patients with a mandibular implant-supported denture have a maximum bite force of 60 to 200% greater
than patients with conventional dentures. Studies done by Haraldson et al. (1988) and Fontijn-Tekamp et al. (1998, 2000) have shown that maximum bite force increases as a result of implants. To be able to withstand functional and parafunctional masticatory forces, the denture base of the prosthesis must be strong. This is especially important with implant-supported overdentures, wherein relief of acrylic is needed to provide space for the attachment housings, resulting in a thinner denture base. A number of overdenture fractures have been demonstrated in areas where copings are present. Because of the increased forces and thinning of acrylic bases brought by accommodation of implant components and tissue bars, failure of overdentures due to fracture is common. Thus, this aspect of denture fracture and repair should be taken into consideration and should be given more focus. To endure repeated masticatory loads and resist plastic deformation, acrylic resin materials should exhibit fatigue resistance and a high proportional limit. The ability of a material to resist catastrophic failure under flexural load is called flexural strength. Denture success greatly depends on high flexural strength since alveolar resorption is a continuing, irregular process which leads to tissue-borne prosthesis being unevenly supported. The ability of the repair material to sustain higher flexure in combination with high resistance to cyclic loading may render acrylic less prone to clinical failure. Repair materials used for direct pick-up of attachment housings are therefore the focus of the study.

**Repair Materials.** A variety of materials have been used in dental practice to repair fractured acrylic resin dentures. These include auto-polymerized (self-cured) acrylic and visible light-polymerized (light-cured) acrylic resins. More residual monomer has been observed in self-curing acrylic resins than heat-cured denture base
acrylic resins, which acts as a plasticizer thereby affecting the mechanical properties of polymerized resins.\textsuperscript{10}

In a study done by Stipho et al., Triad Visible Light Polymerized (VLP) reline material produced the greatest bond with the Triad VLP denture base resin, however, when used with PMMA acrylic resin groups, it produced a very low after-repair tensile and shear bond strengths.\textsuperscript{11} In 1995, Lewinstein et al. reported that there was no difference in bond strength when heat-cured resin specimens were repaired with self-cured resin or Triad Visible Light Cured (VLC) resin if the specimens were pre-treated with monomer.\textsuperscript{12} But in the study done by Dar-Odeh et al. which evaluated self-cured and visible light-cured acrylic as denture repair materials, the specimens repaired with self-cured acrylic had greater values of modulus of rupture than those repaired with VLC, and were considered highly significant ($p \leq 0.001$).\textsuperscript{12} This was supported by Vojdani et al. (2009) and their study revealed that denture repair with self-cured acrylic showed a higher (60.3MPa) transverse strength value than those repaired with light-cured acrylic (51.3MPa).\textsuperscript{13} However, the use of VLC resin material was still considered a suitable material for denture repair since it is satisfactory in terms of strength according to some authors (Andreopoulos et al., 1991; Craig et al., 1992).\textsuperscript{12}

Due to simplicity and quick repair, the use of auto-polymerizing acrylic resins is popular, however it often re-fractures at the repair site. Usually, re-fracture of dentures occur at the interface junction of the original base and repair materials\textsuperscript{4}, thus bond strength produced between the base and repair material is important. To improve bond strength, mechanical modifications such as grinding with burs, airborne-particle abrasion and laser treatment to increase surface area or chemical pre-treatments of acrylic resins
using methyl methacrylate or organic solvents such as acetone, chloroform, methylene chloride may be used.  

Acceptable repair of dentures depends on satisfactory mechanical properties, shear bond strength and adhesion to the fractured parts. Causes of insufficient bond durability may be attributed to contamination of the bond area, thermal stress and cyclic flexural stress during mastication. Another factor that can cause a decrease in bond strength and durability may be the water content in the denture base resin absorbed during laboratory processing and intraoral use. It is hypothesized that water content in the denture base resin may possibly influence bonding of repair resin because these absorbed water molecules presumably diffuse into the polymer chains of the denture base forcing them slightly apart. In a study done by Minami et al., however, water content did not influence the bond strength of autopolymerizing resin to denture base, rather, it was influenced by resin type, thermal cycling and surface treatment. Also, the study revealed that resistance to debonding due to thermal cycling was enhanced with the use of mechanical and chemical surface treatments of denture base resins. In 2009, Vojdani et al. reported on the effect of chemical surface treatments on the transverse strength of repaired denture resins. The groups without surface treatment showed significantly lower transverse strength than those with pre-treated surfaces (p-value < 0.0001). In addition to this, the study also reported that the transverse bond strength of self-cured acrylic to heat-cured acrylic was significantly higher than the transverse bond strength of light-cured acrylic to heat-cured acrylic.

Successful denture repair of implant overdentures depends on the phenomenon of adhesion, not only between the denture base resin and the repair material, but adhesion
between the attachment housing and the repair material as well.

**Silanation.** Silanes are commonly used in dentistry, mainly to promote adhesion between dissimilar materials, such as acrylic and metal. To ensure durable retention-free bonding to resins, metals can be coated with a silane adhesive layer using Rocatec (3M ESPE, Minnesota, USA). Rocatec may be referred to as cold silanization because it takes place without any change in temperature. It uses a tribochemical method for silicoating surfaces which involves creating chemical bonds by application of mechanical energy through the form of rubbing, grinding or sandblasting. The Rocatec system has 4 components: Rocatec Junior, Rocatec Pre, Rocatec Plus/Soft, and Sil. Rocatec junior is a coating unit, which includes a container with blasting regulator, an air hose, foot switch and a blasting nozzle. This universal bonding system involves 3 processes which makes use of the next 3 components. Rocatec Pre, composed of 110µm aluminum oxide sand, is used to clean and activate the surface. After sandblasting with this high-purity aluminum oxide, a uniform pattern of surface roughness is created. Following cleaning, the coating sands, Rocatec Plus or Rocatec Soft, are used. These coating sands are silica-modified aluminum oxide, and these come in 2 particle sizes depending on what surface you are preparing. Rocatec Soft (30µm) is used for fine or small surface restorations like crowns and bridges; and Rocatec Plus (110µm) for larger surface areas like partial dentures. As the substrate is blasted, excitation of the involved surface and sand at the atomic and molecular level is produced creating a triboplasma, which is a gaseous discharge induced by tribological stimulation such as material abrasion, emission of photons and electrons. To further demonstrate, other examples of triboplasma include lightning and sparks from striking steel. The thin layer of silicon dioxide on the Rocatec Plus/Soft
becomes impregnated on the surface of the substrate up to a depth of 15µm. The last step would be the application of Sil silane resin primer. This is necessary to form a bond with the resin. Silane, being a dual molecule, produces the bond between the silicatised surface and methacrylate groups. In summary, Rocatec produces adhesion by creating a uniform pattern of surface roughness, which ensures microretentive anchorage of the resin.21

In 1993, May et al. reported that when 110µm alumina was used to pre-treat Titanium and coated by a silicoat material, the shear bond strength between Titanium and heat-cured PMMA based resin was increased by 60%.23 In the same light, Guggenberger concluded that the shear bond strength between PMMA based resin and cast metal alloy was increased with Rocatec pre-treatment.24

This was further supported by another study done by May et al. in 1995. The study compared grade 2 Titanium that was pre-treated by 110µm alumina air abrasive and the Rocatec material and grade 2 Titanium that was not pre-treated prior to processing of denture base resin. The pre-treated group had shear bond strength of 23.8±1.78 MPa that was 68% greater than the non-pre-treated group (16.1±1.61 MPa). These results confirmed that the use of 110µm alumina air abrasive and the Rocatec material as a pre-treatment of grade 2 Titanium significantly increases its shear bond strength to PMMA based resin.25

This study was done to test the null hypothesis that there is no difference in the flexural strength of acrylic blocks after direct pick-up of attachment housings using 4 distinct methods: self-cured acrylic, light-cured acrylic, self-cured acrylic with silanated attachment housing, and light-cured acrylic with silanated attachment housing.
MATERIALS AND METHODS

In vitro testing of the strength of acrylic blocks after attachment pick-up was done.

Eighty heat-cured polymethylmethacrylate denture blocks were prepared by investing metal patterns in conventional denture investment flasks. A silicone-gypsum mould technique of investing was done to facilitate removal of the metal patterns from the flask. The metal patterns were invested in a high-viscosity silicone impression material for the dental laboratory (Sil-Tech; Ivoclar Vivadent Inc, New York, USA). After the silicone material had set on the lower half of the flask, another layer of silicone impression material was added to cover the patterns and the mould. Subsequently after setting, the upper half of the flask was further supported entirely by gypsum material.10,26 After the invested material had set, the flasks were separated, and the metal patterns were removed from the silicone mould. Lucitone 199 (Dentsply Trubyte, Pennsylvania, USA) heat-cured denture base resin was proportioned and mixed following manufacturer’s instructions. The resin was packed and polymerized in a water tank at 170°F for 9 hours. After processing, all specimens were bench-cooled for 30 minutes.13

All specimens were trimmed to 11.5 x 9.1 x 39.5 mm, and were assessed for porosities. They were finished in a polishing machine using 320, 400, 600, 1000 grit sandpaper for 20 seconds on each of the four sides. Finish polishing was done using 1200
grit sandpaper for 10 seconds per side followed by a polishing rag and an alumina-oxide slurry solution for 10 seconds per surface. This left the blocks with a final dimension of $11 \pm 0.5 \times 8 \pm 0.5 \times 38 \pm 0.5$ mm.

The Titanium housings (Biohorizons, Alabama, USA) that were used had a dimension of $5 \text{mm diameter} \times 3.2\text{mm height}$. These are composed of Ti-6Al-4V; which meets the specification of American Society for Testing and Materials (ASTM) F136. Each housing was composed entirely of the Titanium alloy that was subjected to an electrolytic passivation process called anodization, to control the oxidized layer formation on the Ti alloy surface. This in turn gives the housing its gold color. The thickness of an anodized oxide layer ranges from 500 to 1000 angstroms.\textsuperscript{27}

The manufacturer suggested that at least 1.5 mm of clearance is needed around and above each housing for maximum retention in the denture base\textsuperscript{28}, thus an $8.5 \pm 0.5$ mm diameter $\times 5 \pm 0.5$ mm depth hole was drilled at the center of each denture block using a drill press (Rockwell International, PA, USA). Attachment housings were set in the denture blocks as described below using 4 different repair materials: self-cured acrylic (Acraweld; Henry Schein, New York, USA) for Group A, light-cured acrylic (Triad Gel; Dentsply Trubyte, Pennsylvania, USA) for Group B, self-cured acrylic (Acraweld; Henry Schein, New York, USA) with silanated attachment housing for Group C and light-cured acrylic (Triad Gel; Dentsply Trubyte, Pennsylvania, USA) with silanated attachment housing for Group D. Specimens were randomized to the four groups using a randomly-permuted blocks assignment scheme. Titanium housings for Groups C and D were silanated using the Rocatec System (3M ESPE, Minnesota, USA). All materials were used following manufacturer’s instructions. After attachment pick-up,
the repaired side was re-polished with 1200 grit sandpaper for 20 seconds.

**Group A.** After cleaning and drying of the drilled PMMA surface, liquid methyl methacrylate monomer was brushed on the exposed surface for 180 seconds to enhance adhesion of the repair material and the denture base resin.\(^\text{13}\) Self-cure acrylic was applied using the “salt-and-pepper” technique. Once the resin filled \(\frac{3}{4}\) of the hole, the denture block was inverted and placed over the titanium housing, simulating clinical attachment pick-up. The denture block was pressed against a glass slab for 10 minutes. Using “salt-and-pepper” technique, additional self-cure resin was placed on the repaired side to fill any voids. Once set, the repaired surface with the attachment housing was re-polished.

**Group B.** Triad bonding agent was applied after cleaning and drying of the drilled area. It was left to settle for 2 minutes and then cured for another 2 minutes in the Triad curing unit (Triad 2000; Dentsply Trubyte, Pennsylvania, USA). Flowable resin was subsequently used to fill \(\frac{3}{4}\) of the hole, and the denture block was inverted to pick-up the titanium housing, simulating clinical attachment pick-up. The denture block was pressed against a glass slab and the resin was cured for 4 minutes while inverted, using a portable light-curing unit (Elipar S10 LED Curing Light; 3M ESPE St. Paul, Minnesota). Additional flowable resin was added around the housing to fill any voids and was initially cured for 4 minutes using a portable light-curing unit. Air Barrier Coating was applied on the light-cured resin to prevent inhibition of polymerization by oxygen\(^\text{1}\) and each block underwent final curing in the Triad curing unit for another 8 minutes. The repaired surface was then re-polished.

**Group C.** Using Rocatec Junior, an abrasive blasting system, the titanium housing was sandblasted with silica-modified 30\(\mu\)m aluminium oxide (Rocatec Soft). A
blast pressure of 2.8 bar was used for sandblasting. This was done to assure an adequate high level of energy to create the triboplasma. The surface was sandblasted at right angles from a distance of 1 cm for 15 seconds all around the titanium housing. It was then silanated for 15 seconds using RelyX Ceramic Primer (3M ESPE, St. Paul, Minnesota). Instead of using 3M ESPE Sil, 3M ESPE RelyX Ceramic Primer was used since it is made up of the same chemical compound (Methacryloxypropyltrimethoxysilane), the only difference is the water content and lack of Methyl Ethyl Ketone in the RelyX ceramic Primer.29, 30 Water evaporates slower than a ketone thus drying time is critical; therefore after silanation it was dried with air using a blow-drier for 15 seconds prior to attachment pick-up for adequate dryness of the silane solution since this was necessary to prevent incorporation of solvent molecules in the resin bonding layer which may weaken the interface.21 Pick-up was accomplished using self-cure acrylic and with the same protocol as Group A. Once set, the repaired surface was re-polished.

**Group D.** Using Rocatec Junior, an abrasive blasting system, the titanium housing was sandblasted with silica-modified 30 μm aluminium oxide (Rocatec Soft) under a blast pressure of 2.8 bar. This was done to assure an adequate high level of energy to create the triboplasma. The surface was sandblasted at right angles from a distance of 1 cm for 15 seconds all around the titanium housing. It was then silanated for 15 seconds using 3M ESPE RelyX Ceramic Primer, dried with air using a blow-drier for 15 seconds prior to attachment pick-up. Adequate dryness of the silane solution was necessary to prevent incorporation of solvent molecules in the resin bonding layer which may weaken the interface.21 Attachment pick-up was accomplished using light-cured acrylic and with the same protocol as Group B. Once set, the repaired surface was re-
Continued water uptake after curing may cause denture base materials to undergo changes. That is why all specimens were immersed in 37.6°C distilled water for a minimum of 30 days\textsuperscript{12} for saturation in a 37°C incubation chamber (Queue Systems Inc, WV, USA). This is longer than that specified in ISO specification 1567:1999.\textsuperscript{1}

Final dimensions were recorded using a digital vernier caliper (Mukesh Trading Co, India). The flexural strength of the repaired denture blocks with the attachment housings was measured during a three-point bending test using an Instron model 5565 testing machine (Instron Industrial Products, Grove City, PA). The three point bending jig was set to have a span of 30mm, and a 5000N Instron load cell was used. The testing jig that was used was made of 2 parallel rods, with a third rod centered above, parallel and between the first 2, giving a three point load to the denture block. Force was applied at the center of each block above the repaired area. The test was conducted at a crosshead speed of 5mm/min until failure occurred. Flexural strength values were computed by the Instron software after inputting measurements of the test blocks into the Instron. The force was recorded in Newtons (N). The formula used by the Instron program for determining the flexural strength is:

$$\sigma = \frac{6M}{bh^2}$$

Where \(\sigma\) is the bending stress, \(M\) is the moment about the neutral axis, \(b\) is the width of the specimen, and \(h\) is the depth of the specimen. Calculations of the mean and standard deviations were done. The study utilized a 2x2 factorial design, with factors defined by type of repair material (light-cured or self-cured) and silanation (silanated or not). Results were analyzed using 2-way analysis of variance (ANOVA) implemented
with the SAS® software system. Groups were considered statistically significant with p<0.05.
RESULTS

The mean flexural strength values per group are as follows: self-cured acrylic was 678.4±72.4 Newtons, light-cured acrylic was 550.9±119.3 Newtons, self-cured acrylic with silanated attachment housing was 863.1±87 Newtons, and light-cured acrylic with silanated attachment housing was 543.2±100.8 Newtons (Figure 1). Two-way ANOVA showed significant interaction (p<0.0001), indicating that the effect of silanation is not consistent across repair material type. The interaction between the groups is presented in Figure 2. Tukey’s test was done since there was a significant interaction of the two effects (repair material and silanation). Based on Tukey’s test (Table 1) there was no significant difference in means between non-silanated and silanated for light-cured acrylic groups, but there was for self-cured acrylic groups (p<0.0001). The effects of silanation and repair material type is not additive. The effects of silanation is dependent on which type of repair material was used. Furthermore, the results revealed that self-cured acrylic with silanated attachment housing yielded the highest mean flexural strength values (p<0.0001) and is significantly different compared to the other groups, as shown in Table 1.

Figure 3 (A-D) shows the fracture site in each of the 4 groups. Both the non-silanated and silanated light-cured acrylic groups generally had similar failure type. As shown in Figure 3B and Figure 3D, fracture line in the light-cured acrylic groups was
between the denture base material (heat-cured acrylic) and the light-cured repair material, thus an adhesive failure may be assumed. In the same light, adhesive failure was also seen in the self-cured acrylic groups, only it was between the repair material and the housing itself (Figure 3A and Figure 3C).

Figure 1. Mean flexural strength of Self-Cured (SC), light-cured (LC), Silanated Self-Cured (SSC), and Silanated Light-Cured (SLC) groups in Newtons.
Figure 2. Mean Flexural Strength (Newtons) showing the interaction between the 2 effects: silanation vs repair material type (Interaction p<0.0001). NS=non-silanated, S=silanated, LC=light-cure, SC=self-cure.

Table 1. Tukey's test (Dependent Variable: Flexural Load). LC=light-cure, SC=self-cure, SLC=silanated light-cure, SSC=silanated self-cure group. All interactions were significant except between LC and SLC (p=0.9942).
Figure 3A. Self-cure acrylic group fracture site was between the attachment housing and self-cure acrylic. (SC)
Figure 3B. Light-cure acrylic group fracture site was between the light-cure acrylic and heat-cure acrylic. (LC)
Figure 3C. Self-cure acrylic group with silanated attachment housing fracture site was between the attachment housing and self-cure acrylic. (SSC)
Figure 3D. Light-cure acrylic group with silanated attachment housing group fracture site was between light-cure acrylic and heat-cure acrylic. (SLC)
DISCUSSION

In this study, blocks made of heat-processed denture base material were repaired using 4 different methods: self-cured acrylic, light-cured acrylic, self-cured acrylic with silanated attachment housing and light-cured acrylic with silanated attachment housing. Rocatee Soft was used because the manufacturer recommended using 30µm grain size of the carrier aluminum oxide for surfaces that are highly susceptible to abrasion.\textsuperscript{21} According to Pfeiffer in 1993, the use of 30µm grain size produces the same adhesive strength as the 110µm grain size, but is less abrasive. Since the Titanium housings that were used in this study had an anodized layer, which ranges from 500 to 1000 angstroms\textsuperscript{27}, the 30µm grain size of silica-modified aluminum oxide was used. A 3-point bending test was used to measure flexural strength of each repair method. The test was conducted at a crosshead speed of 5mm/min.\textsuperscript{1, 2, 13, 31} Because of continued water uptake after curing, denture base materials may undergo changes thus all specimen denture blocks were immersed in water for at least 30 days\textsuperscript{12} in a 37°C incubation chamber to allow water saturation. This is longer than the ISO specification 1567:1999.\textsuperscript{1}

The null hypothesis in this study that there is no difference in the flexural strength of acrylic blocks after direct pick-up of attachment housings using these 4 repair methods was rejected.

The results of this study showed that the flexural strength of denture blocks
repaired with self-cured acrylic plus the use of a silanated attachment housing had the highest value compared with using self-cured acrylic alone, light-cured acrylic alone and light-cured acrylic with silanated attachment housing. Furthermore, when the mean flexural strengths of both self-cured acrylic groups were compared with the two light-cured acrylic groups, self-cured acrylic groups rendered higher flexural strength values. This is in agreement with the studies done by Dar-Odeh et al.\textsuperscript{12} and Vojdani et al.\textsuperscript{13} which evaluated self-cured and visible light-cured acrylic as denture repair materials. Specimens repaired with self-cured acrylic showed greater values of modulus of rupture and higher transverse strength values (60.3MPa) than those repaired with light-cured acrylic (51.3MPa). As denture repair materials, self-cured acrylic produces higher transverse strength values and modulus of rupture probably because it produces a greater bond with the denture base material since self-cured acrylic and heat-cured acrylic are both PMMA acrylic resins. Materials with the same composition have better bonding. To further support this, in a study done by Stipho et. al., Triad VLP reline material produced the greatest bond with the Triad VLP denture base resin. However, when used with PMMA acrylic resin groups, it produced very low after-repair tensile and shear bond strengths.\textsuperscript{11} This further explains that visible light polymerized acrylics do not bond well with polymethyl methacrylate. Thus it is probable that in this study that the greater flexural strength values of the acrylic group were due to a better bond between the polymethyl methacrylate (PMMA) based acrylics (self-cured and heat-cured acrylics) as compared with the bond from Triad Gel, which is composed of aliphatic urethane methacrylate with amorphous precipitated silica.

These data show that silanation of the attachment housing with self-cure repaired
blocks increased the bonding of the attachment housing with the self-cured acrylic, rendering a stronger construct. Because of the roughened, partially silica-coated surface produced when 30µm silica-modified aluminum oxide was sandblasted on the attachment housing, the silanation of the housing was able to produce a better bond between the titanium and acrylic resin. Silane being a dual molecule, has one end bonding with the inorganic silicatised surface (Titanium silica-coated surface) and the other end with the organic resin. The alkoxy groups of the silane molecule bonds with the silicatised surface while the methacrylate groups copolymerize with the resin. This results in the production of chemical bond between the metal and the resin.\textsuperscript{21}

In contrast to this, silanation did not produce an increase in flexural strength of the denture block repaired with light-cured acrylic. The difference between the mean flexural strengths of silanated and non-silanated light-cured acrylic groups was not statistically significant. However, it cannot be assumed that silanation did not increase the bond between the light-cure repair material and attachment housing since the mode of failure was between the light-cure repair material and the denture base. An increase in bond strength with the silanated attachment housing is very probable, only it was not recorded since the failure occurred at the bond between light-cured and heat-cured acrylic. A very weak bond formed between the two materials could have caused this failure or it is also possible that there was an incomplete polymerization of the light-cured acrylic since there is only a certain depth that the curing light can reach. Since there is approximately 3mm of heat-cure acrylic before the light could reach the light-cured acrylic material, this might hinder complete polymerization of the said material.

Faot et al in 2009 recommended that the fractured denture base should be repaired
with the same resin it was made of because it will produce a greater fracture strength.\textsuperscript{31} However, due to the length of time for processing, other materials are often chosen by clinicians. Otherwise, if the clinician opts to repair it with a heat-cured material, an indirect pick-up should be done rather than a direct, chair-side pick-up, which will result to more appointments and is outside the scope of the study.

Strength of denture base should be sufficient enough to withstand masticatory forces after direct attachment pick-up to prevent fracture. Thus with the results of this study, it is recommended to pre-treat the attachment housing with silane prior to pick-up with self-cured acrylic for optimal results.
CONCLUSIONS

Within the limitations of this study, the following can be concluded:

1. Flexural strength of self-cured acrylic with a silanated attachment housing was significantly higher than self-cured, light-cured, and light-cured acrylic with silanated attachment housing groups.

2. Flexural strength of self-cured acrylic with and without silanation of attachment housing was significantly higher than the light-cured acrylic groups.

RECOMMENDATIONS

The author recommends that in the future studies, mechanical tests should be done in a wet environment to simulate the condition in the oral cavity. Instead of using a static load, fatigue testing would be more beneficial. To increase the bond between the light-cured acrylic and heat-cured acrylic, the use of methylmethacrylate (monomer) instead of the Triad Bonding Agent may produce different results, as recommended by Lewinstein et. al. (1995) as well as additional mechanical modifications to increase the surface area.
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