ABSTRACT

Background: Residual monomer is one of the undesirable factors affecting the properties of acrylic resin denture bases. This study compared the influence of adding silanated glass fiber (SGF) to two types of acrylic (heat & light cured resin) on the amount of residual monomer methyl methacrylate (MMA) at different periods of time.

Materials and Methods: Specimens of heat and light cured denture base materials reinforced with (2 mm length, 2 wt%) (SGF) were measured for their amount of residual monomer (MMA) by using high-performance liquid chromatography (HPLC) after (3 days, 7 days, 14 days, and 30 days).

Results: The amount of residual monomer in reinforced groups with (SGF) either heat or light cured resin was less than non-reinforced groups. The amount of residual monomer in heat cured resin was higher significance than light-cured resin and the amount of residual monomer of both types of acrylic decreased with time increased.

Conclusion: The addition of 2% silanated glass fiber to both heat cured & light cured resin slightly decreased the amount of residual monomer.

KEYWORDS

Glass fiber, heat cure, light cure, monomer

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INTRODUCTION

Polymerization of denture base resins can be accomplished with different processing methods. Despite the various methods used to initiate the polymerization reaction, the conversion of monomer to polymer is not complete and some non-reacted monomers called residual monomers will be left. Residual monomer considered undesirable property it may diffuse from the acrylic resin into saliva (1) and to the mucous membrane resulting in irritation or allergic reaction (2, 3, 4).

Residual monomer had an adverse effect on the mechanical properties of denture base resin, such as hardness, water sorption, tensile strength (5, 6), and flexural strength (8). A number of methods have been developed to determine the level of residual methyl methacrylate monomer such as infrared spectroscopy (9) and gas chromatography (10, 11). But high performance liquid chromatography (HPLC) has also expanded its application in analytical chemistry (12, 13). There are some types of material that added to acrylic resin in order to improve its mechanical properties. Glass fiber reinforced polymers enhance the mechanical properties of the polymers especially...
the silanated glass fiber because of their good initial bonding between the glass fiber and polymers via
the interface that made from silane coupling agent
\(^{14}\). Some authors reported that the use of glass fiber
reinforcement in heat-cured acrylic resin increase
the release of residual methyl methacrylate \(^{15,16}\). Although this increase was significant, lowest residual
MMA content was found successively in reinforced
long and short-term terminal boiled heat polymerized
and microwave-polymerized like in unreinforced
groups\(^{17}\).

MATERIAL AND METHODS

A. Heat cure base material: Heat cured acrylic
(Densply, Stellon QC-20 England) used to make 80
plates of dimensions (50x5x2mm) length x width
ox depth respectively. A 40 plates represented the
control which is the denture base materials without
SGF, and 40 plates represented the test which is
denture base materials with (2mm length, 2wt%)
randomly oriented SGF\(^{18}\). The required length of
fibers was obtained by using cutter. An electronic
balance with accuracy)0.0001g( was used to weigh
the fibers to the required weight needed for each
specimen groups. Mixing procedure of fibers with
the heat cured acrylic was conducted by adding
the fiber to the powder using the mortar and pistil,
the heat cured acrylic was mixed in a ratio used in
this study (7.5mg/4ml) powder/ liquid) ratio, brass
plate of dimensions (50x5x2mm) length x width
x depth respectively which was used in silicon
impression for fabrication the acrylic specimens,
the dough acrylic moulded using silicon-stone
mould\(^{19}\) and cured using short curing cycle(90min
at 74C\(^\circ\) followed by 30 min at100C\(^\circ\))\(^{20}\).

B. Light cure base material: light cured (Megadent
Germany were used to make 80 plates of dimensions
(50x5x2mm) length x width x depth respectively. Like the heat cure acrylic a 40 plates represented the
control which is the denture base materials without
SGF, and 40 plates represented the test which is
denture base materials with (2mm length, 2wt%)
randomly oriented SGF. Mixing procedure of
fibers with the light-cured material was performed
by hand and the weighted fibers gradually added
with continuing knead till getting homogenious
materials. Special mould of clear glass was made
of 2mm thickness and had 4slits, each slit of 50mm
length and 5mm width(the same dimension as in
heat cure group) The specimens were polymerized
in the light-cure unit for 4min (according to the
manufacturer’s instruction). another 4min curing
for complete polymerization

Specimens of both heat and light cure were
finished and stored in distal water as the conventional
method used for complete denture fabrication till the
evaluation times for the amount of residual monomer
at 3days, 7days, 14days, 30days. At the end of each
immersion time the specimen were removed and
drilled at low velocity prosthetic engine\(^{10,6}\), 0.5g drill
cutting collected in test tube dissolved in 10% High
performance liquid chromatography HPLC grade
99.8% methanol alcohol as extraction solvent\(^{7}\), for
4 days\(^{21}\) then analysis of the amount of residual
monomer has been done with the aid of HPLC (LC-
2010A HT Shimadzu Japan system equipped with
ODS C18 column (250x0.4mm). Sample solution
was injected and analyzed at room temperature at a
flow rate 0.5ml/min).

Statistical methods

Suitable statistical methods were used in order
to analyze and assess the results. They include
the followings summary statistics of the readings
distribution (mean, standard deviation SD), Student
test (t-test)& the comparison of significant (P-value)
(P≤0.05)

RESULTS

In Table-1, it was cleared that the highest mean
values are (1.348) and (1.1543) that were obtained
from unreinforced and reinforced heat cured resin
groups respectively after 3days, while the lowest
mean values are)0.2771(and)0.2248( were observed
in unreinforced and reinforced groups respectively
after 30days. Also this table shows that there is a
significant difference between unreinforced and
reinforced groups)P≤0.05( after 3days only, while the
difference between the unreinforced and reinforced
groups in the amount of residual monomer after the
)7, 14, and30(days are not significant )P ≥0.05(.

In Table2, shows the highest mean values
)0.3913( and )0.16075( were obtained from measuring
the residual monomer content in unreinforced and
reinforced light cured resin groups respectively after
3 days of waiting in ringer solution. While residual
monomer measurement after 30days, it was observed
that the lowest mean values are )5.30E-03( and
)4.56E-03( for unreinforced and reinforced groups
respectively.

Also In this table, it is observed that there is
none significant difference between reinforced and
unreinforced groups of light cured resin groups at all periods of time examined (P ≥ 0.05), except after 3 days of residual monomer measurement, the result was a highly significant difference between reinforced and unreinforced groups of light-cured resin specimens examined (P ≤ 0.01).

Table 1 and Table 2 illustrated the mean values in percentage & standard deviations of the amount of residual monomer content in heat & light-cured acrylic resin groups with & without SGF at four periods of time also showed the statistical analysis was performed using student t-test. This test shows the comparative significant difference between SGF reinforced groups and unreinforced groups of both heat-cured & light-cured resins.

In Table 3, Student t-test for comparison the amount of residual monomer content between heat and light-cured resin both (reinforced & unreinforced) groups that there is a highly significant difference (P ≤ 0.01) in residual monomer content between heat and light-cured acrylic denture base materials (reinforced & unreinforced) groups for all periods of time conducted in this study except after 7 days between unreinforced groups of both heat and light cured resin the results was significant (P ≤ 0.05).

### Table 1: Mean, Standard deviation & T-test for heat cured acrylic resin

<table>
<thead>
<tr>
<th>Time</th>
<th>Groups</th>
<th>NO</th>
<th>Mean%</th>
<th>SD</th>
<th>Groups</th>
<th>P-value</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days</td>
<td>H</td>
<td>5</td>
<td>1.348</td>
<td>0.26498</td>
<td>H-H2%</td>
<td>0.011</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>H2%</td>
<td>5</td>
<td>1.154</td>
<td>6.7689E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 days</td>
<td>H</td>
<td>5</td>
<td>0.369</td>
<td>0.13276</td>
<td>H-H2%</td>
<td>0.780</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>H2%</td>
<td>5</td>
<td>0.349</td>
<td>5.4834E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 days</td>
<td>H</td>
<td>5</td>
<td>0.274</td>
<td>4.1782E-02</td>
<td>H-H2%</td>
<td>0.978</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>H2%</td>
<td>5</td>
<td>0.272</td>
<td>3.0327E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 days</td>
<td>H</td>
<td>5</td>
<td>0.277</td>
<td>5.9301E-02</td>
<td>H-H2%</td>
<td>0.469</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>H2%</td>
<td>5</td>
<td>0.224</td>
<td>1.9766E-02</td>
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<td></td>
</tr>
</tbody>
</table>

H2%=heat cured specimens reinforced with 2%SGF
H=heat cured specimens without SGF

### Table 2: Mean, Standard deviation & T-test for light cured acrylic resin

<table>
<thead>
<tr>
<th>Time</th>
<th>Groups</th>
<th>No</th>
<th>Mean%</th>
<th>SD</th>
<th>Groups</th>
<th>P-value</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days</td>
<td>L</td>
<td>5</td>
<td>0.391</td>
<td>0.24629</td>
<td>L-L2%</td>
<td>.000</td>
<td>HS</td>
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<tr>
<td></td>
<td>L2%</td>
<td>5</td>
<td>0.160</td>
<td>6.115E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 days</td>
<td>L</td>
<td>5</td>
<td>0.132</td>
<td>3.1707E-02</td>
<td>L-L2%</td>
<td>.457</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>L2%</td>
<td>5</td>
<td>8.94E-02</td>
<td>3.0108E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 days</td>
<td>L</td>
<td>5</td>
<td>3.10E-02</td>
<td>6.8519E-03</td>
<td>L-L2%</td>
<td>.987</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>L2%</td>
<td>5</td>
<td>3.01E-02</td>
<td>5.3572E-03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 days</td>
<td>T</td>
<td>5</td>
<td>5.30E-03</td>
<td>4.1231E-04</td>
<td>L-L2%</td>
<td>.990</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>L2%</td>
<td>5</td>
<td>4.56E-03</td>
<td>1.0644E-03</td>
<td></td>
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</tr>
</tbody>
</table>

L=light cured specimens without SGF
L2%=light cured specimens reinforced with 2%SGF
### Table 3: T-test for comparison between mean values of residual monomer (heat& light) resins percentage

<table>
<thead>
<tr>
<th>Time</th>
<th>Groups</th>
<th>p-value</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>3days</td>
<td>H- L</td>
<td>.000</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>H2% - L2%</td>
<td>.000</td>
<td>HS</td>
</tr>
<tr>
<td>7days</td>
<td>H- L</td>
<td>.011</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>H2% - L2%</td>
<td>.000</td>
<td>HS</td>
</tr>
<tr>
<td>14days</td>
<td>H- L</td>
<td>.009</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>H2% - L2%</td>
<td>.000</td>
<td>HS</td>
</tr>
<tr>
<td>30days</td>
<td>H- L</td>
<td>.004</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>H2% - L2%</td>
<td>.000</td>
<td>HS</td>
</tr>
</tbody>
</table>

H= heat cured specimens without SGF  
H2%= heat cured specimens with 2%SGF  
L= light cured specimens without SGF  
L2%= light cured specimens reinforced with 2%SGF

### DISCUSSION

The residual monomer content of dental acrylic resins has continuing interest, this is due to its cytotoxic effect and tissue reactions. Furthermore, its negative influence on the mechanical properties may adversely affect the clinical performance of the removable denture (5).

There are different types of fibers according to their length and direction but, the use of short cutting randomly oriented SGF in denture base found to be simple technique (22, 18). Also, the use of 2mm length SGF and 2% by weight was proved to improve the mechanical properties of heat cured acrylic (18).

In this study the powder/liquid ratio was used 7.56g/4ml for all specimens of heat-cured resin groups. This higher monomer ratio was used for good impregnation of GF in the polymer. The use of HPLC analysis was suitable for determining the amount residual monomer in denture base acrylic resin (12). Provides accurate estimation of the level of residual monomer in acrylic resins. This technique is a nondestructive method of analysis which does not modify the specimen in the liquid at room temperature. Thus, eliminate heat and yield more accurate results (23). In case of heat cured resin the results showed that were lesser residual monomer in SGF reinforced groups in comparison with unreinforced groups for all periods of time conducted in this study, this might be due to the presence of SGF in the acrylic resin specimens which lead to decrease the amount of polymer in comparison to the specimens without SGF since the powder/liquid ratio was standardized for both reinforced and unreinforced specimens.

These results in agreement with some authors (17) While others supposed that the addition of GF increase the amount of the residual monomer in heat cured resin significantly such results may be due to the methodology that conducted in the specimens preparation in this study which used continuous GF type So the problem of GF impregnation was solved by lowering the viscosity of the polymer by increasing the amount of liquid (monomer).the more monomer added to the mixture, the greater the amount of residual monomer (24).

In case of light cured resin the results revealed that the percentage of mean values of the amount of residual monomer in reinforced groups were lower than in unreinforced group. These results agreed with (25) who suggested that the addition of GF to the composite enhances the degree of conversion and decrease the leached residual monomers. It was seemed that the addition of GF aid in light transmission and light scattering in composite resin, as it was clear that the addition of GF did not increase the amount of residual monomer. From the results, it was appeared that the mean values of residual monomer in heat-cured was significantly higher than light-cured resin. Such results agreed with (26, 27) and disagreed with (28) who reported that light-cured acrylic is free of residual monomer. The lower mean values of residual monomer in light-cured resin may be due to that the material is partially polymerized as the polymer/monomer ratio was prepared by the manufacturer’s machine, also the presence of other constituents other than MMA that respond to light for complete polymerization. Both types of acrylic denture showed decrease the amount of residual monomer with increasing time as shown in previous study (11).

The Addition of silanated glass fiber slightly reduces the amount of residual monomer in heat-cured and light-cured denture base materials. Also the amount of residual monomer of both types of denture base materials decreased with time increased.
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