Cumulative effect of microwave sterilization on the physical properties of microwave polymerized and conventional heat-polymerized acrylic resin

S. Mohammed Shafeeq, S. Karthikeyan, Subash M. Reddy¹, Suma Karthigeyan², R. Manikandan, Arthile Thangavelu³

ABSTRACT

Aims: To evaluate and compare the flexural strength and impact strength of conventional and microwave cured denture base resins before and after repeated sterilization using microwave energy to consider microwave curing as an alternative to the conventional method of sterilization. Materials and Methods: The conventional heat cure acrylic resin (DPI heat cure material) Group A and microwave-polymerized acrylic resin (Vipi Wave Acrylic resin) Group B were used to fabricate 100 acrylic resins samples using a standard metal die of (86 mm × 11 mm × 3 mm) dimensions. The criterion was flexural strength and impact strength testing which had Group A and Group B samples; 50 samples for flexural strength and 50 samples for impact strength measurement. For each criterion, five control samples were taken for Group A and Group B. The samples were stored in water before experimenting. The test samples were subject to four cycles of microwave sterilization; followed by flexural strength testing with a 3-point flexural test in universal testing machine (UNITEK 94100) and impact strength testing with impact testing machine (ENKAY Pr09/E1/16). Results: The physical properties had significant changes for conventionally cured denture base resins, whereas no changes found for microwave-cured resins after repeated sterilization cycles.

KEY WORDS: Denture base resins, flexural strength, impact strength, microwave sterilization

The practice of removable prosthodontics has increased the potential of cross-contamination between dental office and laboratory. Handling of the contaminated or potentially contaminated items may result in self-inoculation and transmission of microorganisms to laboratory personnel or other patient’s dentures and prosthetic appliances.¹

Methacrylate polymers are preferred material for the fabrication of removable dental prostheses. Adequate maintenance of removable prostheses is needed for denture wearers to have an aesthetic, odor-free appliance, and good oral health. Various maintenance procedures by chemical disinfection may alter some material properties during cleaning and disinfection.

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As a simple alternative to overcome the disadvantages of chemical disinfection on prosthesis, the use of microwave energy has been suggested. Microwave energy has currently been used as an effective method of sterilization, yet its effect on resin properties after repeated procedures is not clear. The purpose of this study was to evaluate and to compare the effect of repeated microwave sterilization on physical properties of microwave-polymerized and conventional heat-polymerized acrylic resins.

**Materials and Methods**

The materials for the study were two acrylic denture base materials, conventional heat cure acrylic resin (DPI heat cure material) [Figure 1] and microwave-polymerized acrylic resin (Vipi Wave Acrylic resin) [Figure 2]. In this study, bar samples of dimensions of 86 mm × 11 mm × 3 mm were used which was adapted from the previous studies done by Zappini et al. [2] and Meng and Latta [3] [Figure 3]. The die duplication material was type III dental stone and conventional brass flask and fiber reinforced flask (Vipi STG Flask) [Figure 4] was used for conventional heat cure resin and microwave cure resin, respectively. The resins were manipulated as per manufacturer’s recommendation, packed in dough stage followed by trial closure, and excess flash removal. For conventional heat cure resin polymerization, the flask was immersed in an acrylizer and processed in the temperature of 74° for 9 h and terminal boiling for 30 min (Long curing cycle). Specimens were bench cooled for overnight before deflasking. For microwave polymerization, the FRP flask were kept in the turn table of the domestic microwave oven (LG - model Number 1927C, Max 800 W with the frequency of 2450 MHz) [Figure 5] with 90 W for 6 1/2 min and the flask was reversed to top down position and again for 6 1/2 min. Then, the power increased to 360 W for 3 min. [4] Specimens were bench cooled for overnight before deflasking.

A total of 100 samples were fabricated, finished, and polished [Figure 6]; 50 were conventional heat cured resin samples (Group A) and 50 were microwave-cured resin samples (Group B). The criterion was to test flexural strength and impact strength for the samples. Each criterion had 25 Group A and 25 Group B samples for testing. Prior to testing the specimens were stored in water at 37°C for 24 h. This was done because water sorption causes water mobility among resin molecules, and the stress induced during curing can be relaxed resulting in intermolecular relaxation. [5]

**Microwave sterilization**

Fifty samples were for testing flexural strength and fifty samples for impact strength. Sampling was systemized for each testing criterion as below:

In Group A and Group B individually, 5 samples were the control which were not sterilized (T0), and 5 samples were microwave irradiated one time for 3 min at 650 W (T1) after 7 days from storage in water, another 5 samples were microwave irradiated...
second time after 15 days following the same protocol (T2), another 5 samples were microwave irradiated third time after 21 days following the same protocol (T3), and another 5 samples were microwave irradiated fourth time after 30 days following the same protocol (T4). A total of 20 control samples (T0) without microwave sterilization and 80 samples (T1, T2, T3, and T4) with periodical microwave sterilization were segregated for testing. The tested disinfection protocol followed the study by Mima et al.,[4] who showed that microwave irradiation at 650 W for 3 min was effective to sterilize hard chairside relines. The same settings were adopted for this study.

**Flexural strength testing**

Five bars from each group were tested using a 3-point flexural test [Figure 7] (ISO 1567; specification for denture base polymers) for control group and sample groups after each cycle of sterilization. Specimens were placed in a test rig with circular supports 50 mm apart. The plunger and supports were 3 mm in diameter and 10 mm long. A force was applied using a universal testing machine (UNITEK 94100) and a 500-lbs load cell at a crosshead speed of 5 mm/min. The fracture force was recorded in newtons (N), and the flexural strength (F) was calculated per the formula to yield MPa units (Flexural strength) $F = \frac{3PL}{2bd^2}$. Where P is maximum load (fracture load), L is span length (86 mm), b is specimen width (11 mm), d is specimen thickness (3 mm).

**Impact strength testing**

Five bars from each group of samples were tested using an impact testing machine for control group and sample groups after each cycle of sterilization. Specimens were placed in a test slot with a small portion projecting out. When the hammer of the impact testing machine (ENKAY PR09/E1/16) [Figure 8] hits the specimen, the reading at which the specimen breaks gives the impact strength.

Readings for control samples and samples after each cycle of sterilization were recorded and noted separately for flexural strength and impact strength.

**Results**

Statistical analyses were completed using Student’s t-test to find out the significant difference between the two
groups. If \( P < 0.05 \) then it is statistically significant. If the \( P > 0.05 \) then it is not statistically significant \([\text{Tables 1 and 2}]\). The physical properties had significant changes for conventionally cured denture base resins, whereas no changes found for microwave-cured resins after repeated sterilization cycles.

**Discussion**

Acrylic resins have been used for denture fabrication for over 60 years. Oral problems related to poor hygiene of dentures support the need to establish a disinfection protocol that is effective, clinically viable, inexpensive, and easy to comply with.\[^{16}\]

Chemical disinfection of dentures is commonly achieved by soaking in alkaline glutaraldehyde, sodium hypochlorite, aqueous formaldehyde, or enzymatic solutions. These are still controversial because they may alter some material properties and may induce resistance to \textit{candida albicans}. Some alcohol-based disinfectants reduce the flexural strength of non-crosslinked denture base acrylic resins. Surface alteration and roughness may occur by continuous use of some disinfection methods, for example, staining (by soaking in chlorhexidine) or bleaching (by soaking in sodium hypochlorite).

As a simple alternative to overcome the disadvantages of chemical disinfection on prosthesis, the use of microwave energy has been suggested. It is considered an easily accessible, simple chemical disinfection on prosthesis, the use of microwave energy is considered an easily accessible, simple method, yet its effect on resin properties after repeated procedures is not clear.

Webb \textit{et al.} in 1998 did a study to test the \textit{in vitro} efficacy of two methods of denture sterilization (microwave irradiation and sodium hypochlorite soak). The results of his study indicated that microwaving may be a more effective method of denture sterilization than denture soaking in sodium hypochlorite.\[^{7}\]

There have been a number of studies carried out by other investigators in relation to the sterilization of microorganisms by microwave irradiation (Rohrer \textit{et al.}, 1985)\[^{8-10}\] but (Rohrer and Bulard, 1985) was concerned with the sterilization of microorganisms on denture surfaces and its effects on the dentures.

In this study, both conventional and microwave resins were checked for flexural strength and impact strength before sterilization and after repeated four cycles of microwave sterilization. It was observed in conventional resin there was decrease in flexural strength after repeated cycles of sterilization and there was statistically significant increase in impact strength after repeated cycles of microwave sterilization. This might be due to the release of internal stresses introduced during processing and curing.\[^{11}\] Whereas in microwave resin, there was statistically neither change in flexural strength or impact strength, possibly because there may not be much stress induced while microwave processing and curing, unlike conventional resin. Microwave heating is independent of thermal conductivity, and the temperature rises fast in the center of the resin bulk. Therefore, application of rapid heat may be used without the development of a high exothermic temperature.\[^{11}\]

The clinical implication of this study is that microwave sterilization is an alternate method of denture sterilization.

**Table 1:** The \( t \)-test results for impact and flexural strength measurements of the control samples (T0) versus study group samples (T1, T2, T3, and T4) of conventional heat cured acrylic resin

<table>
<thead>
<tr>
<th>Control and study groups</th>
<th>( t )-test for impact strength</th>
<th>( t )-test for flexural strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n )</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard without sterilization cycle (control T0)</td>
<td>5</td>
<td>0.29</td>
</tr>
<tr>
<td>Sterilization cycle I (T1)</td>
<td>5</td>
<td>0.20</td>
</tr>
<tr>
<td>Sterilization cycle II (T2)</td>
<td>5</td>
<td>0.28</td>
</tr>
<tr>
<td>Sterilization cycle III (T3)</td>
<td>5</td>
<td>0.33</td>
</tr>
<tr>
<td>Sterilization cycle IV (T4)</td>
<td>5</td>
<td>0.49</td>
</tr>
</tbody>
</table>

NS: Not significant, S: Significant, SD: Standard deviation

**Table 2:** The \( t \)-test results for impact and flexural strength measurements of the control samples (T0) versus study group samples (T1, T2, T3, and T4) microwave-cured acrylic resin

<table>
<thead>
<tr>
<th>Control and study groups</th>
<th>( t )-test for impact strength</th>
<th>( t )-test for flexural strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n )</td>
<td>Mean</td>
</tr>
<tr>
<td>Standard without sterilization cycle (control T0)</td>
<td>5</td>
<td>0.32</td>
</tr>
<tr>
<td>Sterilization cycle I (T1)</td>
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<td>0.20</td>
</tr>
<tr>
<td>Sterilization cycle II (T2)</td>
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<td>0.42</td>
</tr>
<tr>
<td>Sterilization cycle III (T3)</td>
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<td>0.45</td>
</tr>
<tr>
<td>Sterilization cycle IV (T4)</td>
<td>5</td>
<td>0.48</td>
</tr>
</tbody>
</table>

NS: Not significant, S: Significant, SD: Standard deviation
for microwave-cured acrylic resins which can be carried out without any significant alteration in the physical properties of the denture base resins even for long-term use.

The limitations of these studies are that it has utilized only a specific shape of the specimen and complex shapes such as complete dentures are not used for this study. Further studies with such complex shapes are necessary to confirm the results of this study. Further cycles of sterilization should be checked for dimensional change, flexural properties, impact strength, to confirm the results of this study.

**Conclusion**

Within the limitations of this study, it was concluded that microwave sterilization is an alternative method of routine sterilization for microwave cured complete dentures, without any change in the physical properties of the denture base material and it is not a suitable method for sterilization of conventionally cured complete dentures.

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Nil.

**Conflicts of interest**

There are no conflicts of interest.

**References**