The Effect of Repeated Microwave Irradiation on the Dimensional Stability of a Specific Acrylic Denture Resin

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Abstract

Purpose: To determine the dimensional stability of a poly(methyl methacrylate) (PMMA) acrylic resin when subjected to multiple sessions of repeated microwave irradiation at power settings of 700 and 420 W.

Materials and Methods: Twenty standardized denture bases were fabricated using a PMMA resin. Points of measurement were marked on each denture base with a standardized template, and the distances between points were recorded using a digital microscope. The denture bases were randomly placed into two experimental groups of 10 bases each. Individual denture bases were placed into a glass beaker containing 200 ml of room temperature deionized water and then exposed to either 700 or 420 W of microwave radiation for 3 minutes. The denture bases were allowed to cool to room temperature, and measurements between points were recorded. This process was carried out for two microwave periods with measurements being completed after each period. The data were then analyzed for any significant changes in distances between points using a Student’s t-test.

Results: All denture bases experienced 1.0 to 2.0 mm or approximately 3% linear dimensional change after each period of microwaving. Results were significant with all t-tests having values of \( p < 0.05 \).

Conclusion: This report showed that the denture bases deformed significantly under experimental conditions at either 700 W for 3 minutes in 200 ml of water or 420 W for 3 minutes in 200 ml of water.

Acrylic resin material was first introduced 1937 by W. H. White with its use becoming extremely popular in denture fabrication.¹ The material itself exhibits many superior esthetic and physical properties over previous denture materials. Despite its superior properties, acrylic resin is a porous material, a major drawback in the oral environment. The resulting effect of this porosity is that dentures made from acrylic resin can be hard to clean and have the ability absorb infectious material, which can act as a catalyst for denture stomatitis.²

Many people do not clean their dentures satisfactorily and may misuse chemical cleansers leading to the deterioration of acrylic dentures. Patients in long-term care facilities are often found to be unable to brush their dentures adequately due to poor dexterity or visual acuity, dementia, and disease.³,⁴ Even if denture cleansers and methods of cleansing are employed properly, there is a reduction but not complete elimination in the number of microorganisms present on the dentures. Dentures in this state can serve as reservoirs for microorganisms in which to reinoculate the wearer.³

Several methods of cleansing have been developed to reduce the presence of microorganisms on dentures. Methods range from removing dentures from the mouth so they are not worn continuously, allowing oral tissues to recover, to the use of antifungal agents such as Nystatin and Amphotericin B.²,⁴,⁵ Current established methods have not been proven to be completely effective in preventing or eliminating the occurrence of denture stomatitis.⁴ Therefore, alternative disinfecting methods are being pursued, including the use of microwave irradiation.⁵

Microwave irradiation of dentures is accomplished by placing a denture in a container of water heated with a conventional microwave at low wattage until the water boils. It has been touted as a safe, simple, and effective low-cost disinfection method for treating dentures and treating denture stomatitis, yet in vitro studies have given conflicting results as to how microwave radiation affects the acrylic resin denture.⁶ When an acrylic resin is subjected to temperatures greater than 71°C, the material enters into the range of its glass transition temperature T, and can undergo plastic deformation.⁷,⁸ Whether
Effect of Microwave Irradiation on Denture Resin Stability

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Materials and methods

Twenty standardized acrylic resin denture bases were fabricated from Lucitone 199 (Lucitone 199; Dentsply International Inc, York, PA) on standardized stone models (Microstone; Whip Mix Corporation, Louisville, KY) poured from a single duplication of a metal cast of an edentulous maxillary arch (Fig 1). A single standardized 4.06-mm thick spacer, fabricated from vacuumed-down clear mouth guard material (Ethylene-Vinyl Copolymer; Buffalo Dental Mfg, Syosset, NY), was placed on top of the cast to achieve an even thickness of acrylic resin throughout the denture base. The spacer was sealed down using a thin bead of denture adhesive (Poligrip; GlaxoSmithKline, Moon Township, PA). The casts were then invested in standard two-piece brass flasks. All stone used for investing was measured and mixed to manufacturers’ instructions (Microstone and Mounting Plaster; Dentsply International Inc.). When the stone was set, the flasks were opened, and the spacer removed. The evacuated space was replaced with Lucitone 199, measured, and mixed to manufacturers’ directions.10,12

The Lucitone 199 was then packed once and put under 3500 psi pressure using a pneumatic denture press (Coe-bilt; Coe Laboratories Inc., Chicago, IL) for 10 minutes and then placed in a denture bath (Hanau Curing Unit; Hanau Engineering, Inc., Buffalo, NY) for the recommended long curing time of 9 hours at 72°C. The denture bases were then cooled for 1 hour to reach room temperature and deflasked following manufacturers’ instructions. The bases were removed from the cast, and the acrylic flash was removed from the periphery of the specimens using an acrylic bur. No surfaces were polished, as that would have changed the consistent thickness of the specimens. The denture bases were then placed and stored at room temperature (21°C) in deionized water for 48 hours prior to being measured, and stored continuously in the deionized water except when being measured.17

The denture bases were fabricated in two separate experimental groups of 10. Bases were then randomly assigned numbers 1 to 10, and a series of 7 points were placed on the intaglio surface of the denture bases using a standardized template with a fine felt tip marker. These points would be used as references to measure changes in the dimension of the denture base (Fig 2).

The distances between the points on the denture bases were then measured and recorded using a digital microscope (Keyence digital optical microscope [VHX-600]; Keyence, Elmwood Park, NJ) under 5× magnification, measuring to 10⁻² mm. The denture bases were measured in two halves due to the size of the specimens and the inability for the entire denture base to be displayed on the computer monitor (Fig 3). Each measurement was recorded three times and then averaged. The denture bases were mounted on the digital microscope stage using modeling clay and leveled with a surveyor’s level to provide repeatability of measurements and to reduce variations in measurement as the material deformed. After the initial measurement, the denture bases were then subjected to microwave radiation at either 700 or 420 W depending on the experimental group using a 700 W 0.7 cu ft microwave with rotating turntable (Magic Chef Microwave Oven; MC Appliance Corporation, Wood Dale, IL). Each of the denture bases were individually

Figure 1 Maxillary edentulous cast.

Figure 2 Denture base with points of measure marked.
placed and submerged in a standard 500 ml glass beaker filled with 200 ml of deionized water at 21°C. The bases were then exposed to microwave radiation one at a time for a duration of 3 minutes for each specimen. This brought the water in the flask up to boiling at approximately 1.5 minutes. After the 3 minutes had elapsed, the flask with the denture base specimen was removed and allowed to cool on the bench top until room temperature was again reached. This procedure was repeated for all 20 denture bases.

The denture bases were subjected to two separate periods of microwave radiation each 48 hours apart. Measurements of the distances between points labeled on the denture bases were then recorded 24 hours after each period of microwave radiation exposure. The measurements were as follows: (1) initial measurement as a base or premicrowave exposure state (2) first measurement after one period of microwaving (3) second measurement after a second period of microwaving. All data were recorded and subjected to Student t-tests using spreadsheets (Excel; Microsoft Corporation, Redmond, WA) to test for the significance of measurements between each of the two trial groups at 700 and 420 W.

Results

All acrylic resin denture bases exhibited 1.0 to 2.0 mm or approximately 3% linear change in all recorded measurements after each period of microwaving (Tables 1 and 2). Results were significant, with all t-tests having the values of \( p < 0.05 \) for each distance between the measured points (Figs 4–7; Table 3).

Denture bases subjected to 700 W of microwave radiation showed a reduction in the distance measured between reference points after the first period of microwave radiation and subsequent expansion in distance between reference points after the second period of microwave radiation. The denture bases subjected to 420 W of microwave radiation showed an opposite effect of expansion between reference points after the first period of microwave radiation and subsequent contraction between reference points after the second period of microwave radiation.

Deformation in all groups appeared very uniform, even between each of the individual bases of each experimental group (Table 1). After exposure to microwave radiation, none of the denture bases returned to their original measured dimensions. The greatest deformation was found when measurements were documented across the complete denture base length, width, and diagonal measurements, with the greatest change observed between the first and second periods of microwave radiation (Tables 1 and 2).

Discussion

The purpose of this study was to test whether acrylic resin denture bases will exhibit dimensional stability when subjected to multiple cycles of microwave radiation. Two testing protocols, 700 W of microwave radiation for 3 minutes and 420 W of microwave radiation for 3 minutes, were selected based on current published research data. Several studies have found that 650 W of microwave radiation for 3 minutes is effective in reducing and even disinfecting acrylic dentures. What has not been determined is whether 650 W of microwave radiation for 3 minutes has stable or unstable consequences on the acrylic denture resin. As previously stated, studies have not been conclusive as to their agreement with regards to the dimensional stability of irradiated acrylic denture resin.
vary greatly in the type of acrylic resin tested, the configuration of the test material, whether they are acrylic resin disks, rectangular sticks, standardized denture bases, or full-form complete dentures.

A conventional 700 W microwave with turntable was selected for this study due to having a close comparison to the 650 W used in many of the prior studies and common availability. Many studies are arcane in that the protocols used to disinfect dentures with microwave radiation are beyond what an average person would use. In the United States, 650 W microwaves are uncommon and finding a microwave with higher wattage that can be reduced to exactly 650 W are not always available. The premise behind microwave disinfection is that it should be simple and easy for the average person to accomplish. What advantage is there to this technique if it is not accessible? The second 420 W group was selected due to a recent article by Senna et al, who demonstrated that a lower wattage of 450 W was also effective in disinfecting acrylic resin with possible reduced denture stability but unknown physical effects on the denture resin.  

This study offered strict controls to eliminate variability or experimental error that can be introduced through the processing and even measurement of the denture bases. All materials were weighed and processed specifically to manufacturers’ instructions. Denture bases were mounted and leveled before measuring to reduce the influence of a 3-D deformation and to provide an increase in the reliability and repeatability of measurement.

The experimental results showed great consistency between all measurements and experimental groups. The results demonstrate that the deformation of the acrylic denture bases were uniform when exposed to heat. This fact can most likely be accounted for due to uniform heating with the denture base being placed in a beaker of water, which may explain the findings of Basso et al, that disinfection is improved when specimens are irradiated while immersed in water.

Craig reports that heat distortion in acrylic denture resin can occur between $71^\circ C$ and $90^\circ C$. The water boiling point temperature of $100^\circ C$ is well beyond the $T(g)$ of the resin material. This explains why deformational changes were observed after each period of microwave radiation exposure. Yet several questions remain unexplained as to what is actually happening on a molecular level within the acrylic. Is the deformation that occurred related to the rearrangement of molecular particles and the release of internal stresses captured in the material during processing? Why would the acrylic expand or contract uniformly? Would uniform expansion and contraction continue upon repeated exposure to microwave radiation? Is this deformation permanent? Does this pattern follow a wave pattern, such as a sine wave as suggested by the data? Lastly, why did the acrylic resin appear to first expand and then contract for the denture bases tested at 700 W and have the opposite effect of contracting then expanding for the denture bases tested at 420 W? It is suggested that further investigation be accomplished to study the behavior of the acrylic denture resin and to determine a protocol that does not cause significant deformation of acrylic dentures.

### Table 1

<table>
<thead>
<tr>
<th>Values per line segment (mm)</th>
<th>Standard deviation</th>
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<tbody>
<tr>
<td></td>
<td>Initial</td>
</tr>
<tr>
<td><strong>D to G</strong></td>
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</tr>
<tr>
<td>700 W</td>
<td>55.83</td>
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<tr>
<td>420 W</td>
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<td><strong>F to C</strong></td>
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<tr>
<td>420 W</td>
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<tr>
<td><strong>E to B</strong></td>
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<tr>
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<td>46.10</td>
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<tr>
<td>420 W</td>
<td>45.58</td>
</tr>
<tr>
<td><strong>D to F</strong></td>
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</tr>
<tr>
<td>700 W</td>
<td>51.11</td>
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<tr>
<td>420 W</td>
<td>50.67</td>
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### Table 2

<table>
<thead>
<tr>
<th>Line segment</th>
<th>Percent linear change of line segments per period of microwave irradiation</th>
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<tr>
<td></td>
<td>Initial vs. first</td>
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<tr>
<td><strong>DG</strong></td>
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<tr>
<td>700 W</td>
<td>3.90%</td>
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<td><strong>FC</strong></td>
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<td><strong>EB</strong></td>
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<tr>
<td><strong>DF</strong></td>
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<tr>
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<tr>
<td>420 W</td>
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Figure 4 Denture resin bases.

Figure 5 Denture resin base.

Figure 6 Denture resin bases.
**Conclusions**

It is concluded that the tested denture bases experienced significant deformation under the experimental conditions of either 700 W for 3 minutes in 200 ml of water or 420 W for 3 minutes in 200 ml of water. It is also concluded that the specific acrylic denture resin used in this study experiences uniform expansion and contraction when subjected to microwave radiation.

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**References**

22. Senna PM, Sotto-Maior BS, Silva WJ, et al: Adding denture cleanser to microwave disinfection regimen to reduce the irradiation time and the exposure of dentures to high temperatures. Gerodontology 2013;30:26-31