Evaluation and comparison of the effect of repeated microwave irradiations on some mechanical and physical properties of heat cure acrylic resin and valplast (nylon) denture base materials

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ABSTRACT

Background: Microwave irradiation has been considered for denture sterilization/disinfection instead of chemical solutions since it has no expiration date and does not induce resistance to the microorganisms. The aim of this study was to evaluate the effects of repeated microwave disinfection on heat cure and valplast (nylon) denture base materials in some mechanical and physical properties.

Material and method: A total No. of 320 specimens (80 maxillary denture bases and 240 specimens) were prepared in this study, then divided into two main groups according to the type of material used (heat cure resin and valplast resin). Each main group was subdivided into four subdivisions according to the type of test used (Transverse strength test, Surface hardness test, Surface roughness test, and fitness test), for each test 40 samples were divided into four groups according to the number of cycles of microwave disinfection that were applied (control, 1 microwave cycle, 3 microwave cycles, and 7 microwave cycles). The term cycle refer to 3min of microwave disinfection at 680 watt. Each specimen was disinfected (subjected to one cycle) one time per a day then transferred to container contain distilled water until another cycle applied in the next day.

Result: The repeated microwave irradiation of heat cure and valplast specimens showed slight but no significant decrease in transverse strength, shore D hardness, and surface roughness. The results of the fitness of denture base materials to stone cast showed an improvement in the fitness of heat cure and valplast denture base materials after the first microwave cycle, and no further improvements in the fitness were taken place after repeated microwave disinfection.

Key Word: valplast (nylon), microwave irradiation, mechanical and physical properties. (J Bagh Coll Dentistry 2011;23(3):6-10).

INTRODUCTION

Polymethylmethacrylate (PMMA) is a derivative of acrylic acid, referred to us as acrylic resin, introduced for use in dentistry and it became the most reliable material for denture construction(1). The development of polymer chemistry produce alternative materials to PMMA such as polyamides (nylon plastics), acetal resins, epoxy resins, polystyrene, polycarbonate resin...etc. all these resins are suited for thermoplastic processing(2)

A nylon, that is suitably stiffened, could be extremely useful in the treatment of those patients for whom acrylic prostheses are not suitable. This would include patients who demonstrate repeated fracture of dentures and those that show tissue reactions of a proven allergic nature.

The chief advantage of nylon lies in its resistance to shock and repeated stressing (3). Removable prostheses may be potential sources of infection since the accumulation of deposits, such as food debris, stains and microbial plaque on denture surface may result in inflammatory changes to the oral mucous. (4).

The available disinfection methods for complete and partial dentures are still controversial because they may alter some material properties and clinical features (5).

For instance, alcohol-based disinfectants reduce the flexural strength of non-crosslinked denture base acrylic resins (6). Surface alteration may occur by continuous use of some disinfection methods, e.g., staining (by soaking in chlorhexidine) or bleaching (by soaking in sodium hypochlorite) (7).

Microwave irradiation has been considered for denture sterilization/disinfection instead of chemical solutions because it requires no special storage, has no expiration date and does not induce resistance to Candida albicans (8). This study designed to evaluate the effect of repeated microwave radiation on some physical and mechanical properties of different types of denture base materials.

MATERIALS AND METHOD

Each main group was subdivided into four subdivisions according to the type of test used (transverse strength, surface roughness, surface hardness and fitness tests), for each test 40 samples were divided into four groups according
to the number of cycles of microwave disinfection that were applied (control, 1MW-cycle, 3MW-cycles, and 7MW-cycles). The term MW-cycle refers to 3 min of microwave disinfection at 680 watt, each specimen was disinfected (subjected to one cycle) one time per a day then placed in distilled water until another cycle applied in the next day. In case of control group, no microwave disinfection were applied.

Table 1: Some of the materials used in the study

<table>
<thead>
<tr>
<th>Material</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat-cured resin for denture</td>
<td>Powder &amp; liquid. Vertex, Holland</td>
</tr>
<tr>
<td>Valplast (nylon) denture base</td>
<td>Nylon grains. USA</td>
</tr>
</tbody>
</table>

Preparation of specimens for surface roughness, hardness, and transverse strength tests.

Metal patterns were constructed by cutting the stainless steel plates with the dimensions of (65mm x 10mm x 2.5mm) length, width, thickness respectively. Mould preparation for heat-cured resin specimens:
The conventional flasking technique for complete dentures was followed in preparation of the mould.
Proportioning and mixing of the acrylic:
All the materials were mixed and manipulated according to manufacture instructions.
Packing and curing of heat cure resin:
The packing process was performed while the acrylic was in dough stage. Curing was carried out by placing the clamped flask in a water bath and processed by short curing cycle (30 min at 74°C) then temperature was increased to the boiling point 100°C for 30 minutes. Finishing, Polishing and conditioning:
All the specimens were finished and polished by the same investigator as follows:
Silicon carbide grit papers starting with grade 120, 240, 320, 400, and 500 were used in sequence during finishing procedure with continuous water cooling. The accuracy of the dimensions was verified with a vernier at three locations of the specimen. Polishing was accomplished by using Tripoli compound with a dry rag wheel in a lathe-polishing machine. Water was used during polishing to avoid excessive heat, which may lead to distortion of the specimens. All the tested specimens were conditioned in distilled water at 37°C for 48 hours before they were tested.

Mould preparation for valplast resin:
The same as in heat cured mould preparation but with wax sprues were prepared - major sprues with 6-8mm in diameter, minor sprues 2-4mm in diameter - and attached to selected areas from one side of the metal pattern and as in (fig 1). Then the upper portion of the metal flask was positioned on top of the lower portion and filled with stone, vibration was done to get rid of the air bubbles. Stone was allowed to harden before the metal flask was opened.

Figure 1: Wax sprues attached to metal patterns for valplast resin

Wax elimination was performed using boiling water then metal flask was opened, the metal patterns were removed from the mould carefully.
Procedure of injecting the valplast denture base material:
The procedure started with the heating cylinder inserted into the slot present inside the electrical furnace as shown in (fig 2) and the furnace was allowed to warm up till it reaches the preset heating which was 287°C, then the heating cylinder removed from the furnace, then valplast cartridge, metal disc and the short solid metal cylinder inserted into the heating cylinder and left inside the furnace for 11 minutes to allow the granules inside the cartridge to melt.

Figure 2: position of heating cylinder before injection procedure.

During that time the flask, that previously preheated inside an oven set at 65°C, removed from the oven and placed inside the injection unit.
in horizontal position in its correct position with the aid of the projection present at the base of the injection unit. In this position the injection opening was at the top surface of the flask. The material was injected inside the flask by the use of the manual injection unit the handle of the injection unit was tightened until both springs on the top side of the unit were closed to give a pressure of 5 bars. After 5 minutes the pressure was released and the flask is removed from the injection unit and allowed for cooling at room temperature.

Finishing, polishing and conditioning of the specimens:
All the specimens were hand finished and polished in the same manner as in heat cued specimens

Microwave disinfection of specimens:
All the prepared specimens were submitted to microwave radiation in order to be disinfected (except the control groups of each material) and as in the following way:
Each specimen was immersed in 150 ml of distilled water inside a cup made of glass and inserted inside a microwave oven which was set at 650 W for 3 min as shown in (fig.3) and that was referred as a "disinfection cycle of microwave irradiation"(11).

Figure 3: Specimen inside microwave oven

Mechanical and physical tests utilized to examine properties
1- Transverse strength test
The transverse strength of specimens was measured in air by three points bending on an Instron 1122 Transverse testing machine. The device was applied with a central loading plunger and two supports with polished cylindrical surface 3.2mm in diameter placed 50mm apart. The test were carried out with a constant cross head speed of 5mm/ minute, the load was measured by a compression load cell of maximum capacity of 500N.
The test specimens were held at each end of the two supports, and the loading plunger placed midway between the supports. The specimens were deflected until fracture occurred. When valplast specimens were tested, the specimens were deflected till the specimen become as a U shape; none of the specimens were fractured and remained one piece

2- Surface hardness test
Surface hardness was determined using durometer hardness tester from type shore D, (hardness tester-TH 210, time group Inc. Italy) which is suitable for acrylic resin material. The instrument consists of blunt-pointed indenter 0.8mm in diameter that tapers to a cylinder 1.6mm. The indenter is attached to a digital scale that is graduated from 0 to 100 units; measurements were taken directly from the digital scale reading. Ten measurements were done on different areas of each specimen (the same selected area of each specimen), and an average of ten readings was calculated.

3- Surface roughness test
The profilometer device (Surface roughness tester SRT-6210, England) used to measure the surface roughness of the specimens, this device is supplied with sharp stylus (surface analyzer) made from a diamond to trace the profile of surface irregularities.
At first the specimen was placed on a fixed and stable base then the device adjusted in a way so that the stylus just touch the surface of the specimen, after that the stylus was traversed toward the right direction along the specimen surface for 11 mm length then the reading appeared on the digital scale.

Denture bases preparation for measuring the fitness at the posterior palatal region.

Cast preparation
Eighty maxillary edentulous casts were prepared from an edentulous silicon mold. The silicon mold was poured with type IV stone mixed at a ratio of 25ml of water to 100gm of powder according to manufacturer instructions. The cast was separated from the mold after 45 min .The mold was left for 15 minutes to pour the second cast and so on.(12)

Record base preparation.
The record base was prepared by using a biostar machine. The cast was placed on the biostar table and dipped in the biostar beads just below the borders; the biostar plate (2mm thickness, clear) was placed in the pressure chamber. After waiting for pressure evacuation, the cast was removed, cutting, trimming and finishing for the plate using biostar burs and sealed with wax on the cast.
Flask preparation for heat-cure denture bases
The cast with the record base was flanked in the lower part of a traditional brass flask with stone mixture. A separating medium was applied to the investment and allowed to dry, and then the upper part of the flask was assembled and filled with the stone. The flask parts were separated after setting of stone, the record base was removed, and a coat of separating medium of fixed volume about 1ml. was applied as a mold separator on the surface of the stone and the cast. Curing, packing and finishing steps were done in the same ways as mentioned before.

Flask preparation for valplast denture bases
The same procedure as mentioned before for heat-cure denture bases, but before the upper part of the flask was assembled wax sprues were prepared into two designs(major and minor) and attached to selected areas from one side of the prepared into two designs(major and minor) and the flask were assembled wax sprues were applied as a mold separator on the surface of the stone and the cast. Curing, packing and finishing steps were done in the same ways as mentioned before.

Microwave disinfection of denture bases:
The same as described before in disinfection of specimens for other tests.

Sectioning and measuring of the base-cast sets:
The location of the cutting line was 39mm from the anterior aspect of the base of the cast, where the whole length of the cast was 52mm. The base-cast sets were transversally sectioned with a manual saw device (2 cuts per second) at the distal aspect of the second molar, anterior to the posterior palatal seal area. The measurement was done at the previously mentioned points by using a travelling microscope (accuracy 0.01 mm).

Table 1: Descriptive data of transverse strength.

<table>
<thead>
<tr>
<th>Studied groups</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>81.22</td>
<td>1.25</td>
<td>79.50</td>
<td>83.00</td>
</tr>
<tr>
<td>MW1</td>
<td>81.01</td>
<td>1.31</td>
<td>79.30</td>
<td>82.90</td>
</tr>
<tr>
<td>MW3</td>
<td>80.88</td>
<td>1.19</td>
<td>78.70</td>
<td>82.70</td>
</tr>
<tr>
<td>MW7</td>
<td>80.75</td>
<td>0.81</td>
<td>79.80</td>
<td>82.70</td>
</tr>
<tr>
<td>Control</td>
<td>71.63</td>
<td>1.79</td>
<td>68.90</td>
<td>73.70</td>
</tr>
<tr>
<td>MW1</td>
<td>71.17</td>
<td>1.74</td>
<td>67.90</td>
<td>73.30</td>
</tr>
<tr>
<td>MW3</td>
<td>70.44</td>
<td>1.46</td>
<td>67.80</td>
<td>72.10</td>
</tr>
<tr>
<td>MW7</td>
<td>70.13</td>
<td>1.49</td>
<td>67.10</td>
<td>72.00</td>
</tr>
</tbody>
</table>

Flask preparation for valplast denture bases
The same as described before in disinfection of specimens for other tests.

Microwave disinfection of denture bases:
The same as described before in disinfection of specimens for other tests.

Table 2: Descriptive data of surface hardness test.

<table>
<thead>
<tr>
<th>Studied groups</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.C.A.</td>
<td>1.245</td>
<td>0.085</td>
<td>1.13</td>
<td>1.35</td>
</tr>
<tr>
<td>MW1</td>
<td>1.220</td>
<td>0.078</td>
<td>1.10</td>
<td>1.32</td>
</tr>
<tr>
<td>MW3</td>
<td>1.212</td>
<td>0.080</td>
<td>1.10</td>
<td>1.33</td>
</tr>
<tr>
<td>MW7</td>
<td>1.210</td>
<td>0.079</td>
<td>1.10</td>
<td>1.33</td>
</tr>
<tr>
<td>Control</td>
<td>4.494</td>
<td>0.302</td>
<td>3.98</td>
<td>5.02</td>
</tr>
<tr>
<td>MW1</td>
<td>4.459</td>
<td>0.454</td>
<td>3.54</td>
<td>5.20</td>
</tr>
<tr>
<td>MW3</td>
<td>4.385</td>
<td>0.476</td>
<td>3.30</td>
<td>5.12</td>
</tr>
<tr>
<td>MW7</td>
<td>4.271</td>
<td>0.549</td>
<td>3.20</td>
<td>5.34</td>
</tr>
</tbody>
</table>

RESULTS
Mean values, standard deviation (SD), maximums (Max) and minimums (Min) of the tests result are presented in Table 1-4.

In general the results of the transverse strength, surface hardness and surface roughness tests for heat-cured acrylic (H.C.A.) and valplast(V.nylon) specimens showed that control group specimens had the highest mean values while MW7 group specimens had the lowest mean values. Two-
way (ANOVA) test revealed a non significant difference (P>0.05) between the different groups of the same material while one-way (ANOVA) showed a highly significant difference (P<0.01) between H.C.A. and V.nylon specimens. The results of the fitness test for heat cured (H.C.A.) and valplast (V.nylon) denture base materials showed that control group specimens at point (c) had the highest mean values of gap spaces while specimens of MW1, MW3 and MW7 groups had the lowest mean values of gap spaces at either point (a) or point (e). The results showed that too highly significant differences at P<0.001 were found at all possible comparisons at the same point of the same group between H.C.A. and V.nylon denture base materials. For H.C.A. and V.nylon denture base materials, there were significant differences between control group and MW1 group at the same point of measurement (a, b, c, d or e) for the same material. There were no significant difference between MW1, MW3 and MW7 groups at the same point of measurement (a, b, c, d or e) for the same material.

DISCUSSION
The results revealed that valplast (nylon) specimens had lesser transverse strength, hardness values and greater surface roughness than heat cure acrylic resin specimens. This difference may be due to the difference in their structural formula (chemical composition), since the nylon have polyamide linkage as a repeating unit that make nylon have more flexibility and fracture resistance than heat cure acrylic with ester linkage with large crystals at the surface of the specimen. The results showed that repeated microwave irradiation had no significant effect on the transverse strength, surface hardness, and surface roughness of the heat cure and valplast resin specimens despite of slight decrease in their values. This may be attributed to the higher polymerization temperature used for the denture base material.

The results for the fitness test showed that Heat cure denture base material showed better fitness (adaptation) than valplast denture base material at the posterior palatal region. This may be due to the difference in the chemical structure between the two materials, since nylon properties are affected by the amount of crystallinity. Nylon shows high mold shrinkage as a result of their crystallinity. (13) The results showed that microwave irradiation improved the fitness of the heat cure and valplast denture bases after one cycle of microwave disinfection and no further improvements were shown after 3 or 7 cycles of microwave irradiation. The improvement in the denture base adaptation may be related to the linear shrinkage that results from the residual polymerization of the acrylic resin during simulated microwave irradiation. In case of valplast specimens linear shrinkage occurred because of evaporation of interstitial polymer matrix as a result of increasing in the water temperature under the influence of microwave radiation.

REFERENCES
12. Mohammed FN. The effect of flasking tension system on the adaptation of acrylic resin denture base in different palatal models and base thicknesses [Master’s Thesis]. Department of prosthetic Dentistry, University of Baghdad; 2007.