

The effect of microwave processing and use of antimicrobial agent on porosity of conventional heat cured denture base resin: An *in vitro* study

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Abstract

Statement of Problem: The occurrence porosity in polymethyl methacrylate, the most commonly used denture base material is a problem. The occurrence of oral candidiasis and other infections has also been reported in denture users.

Purpose: The aim of this study was to evaluate the effect of addition of an antimicrobial agent, silver zeolite on the porosity of denture base resin, which will be an effective tool in the prevention of oral candidiasis among denture wearers. This study also aims to analyze the effect of polymerization technique on porosity in zeolite incorporated dentures to develop a denture base resin which will be easy to process with optimal mechanical and antimicrobial properties.

Materials and Methods: Eighty rectangular resin specimens (65 mm × 40 mm × 5 mm) were divided into one control group (A) and three experimental groups (B – Microwave cured denture base resin specimens, C – Conventionally cured denture base resin incorporated with antibacterial zeolites, D – Microwave cured denture base resin incorporated with antibacterial zeolites) porosity was calculated by measurement of the specimen volume before and after its immersion in water. Data were analyzed using one-way analysis of variance.

Results: The mean values of the percent mean porosity were: A = 0.9555%, B = 0.9590%, C = 0.9630%, D = 0.9695%. No significant differences were found in mean porosity among the groups evaluated.

Conclusion: Within the limitations of this study, it could be concluded that the addition of zeolites did not result in significant porosity and that the use of microwave processing is a viable option for denture processing.

Key Words: Microwave, polymethyl methacrylate, zeolites

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INTRODUCTION

History indicates that the use of new types of materials for restorative purposes has often given way to the development and introduction of new technology and novel methods to the scientific world. The dental community, in its search for better, less expensive, easier-to-handle materials, is often quick to adapt a rising technology for new and different purposes.

The evolution of denture base materials has seen its journey from dependency on naturally occurring materials like wood, ivory, and bone to the invention of vulcanite, a breakthrough in the field of dentistry and finally the evolution of polymethyl methacrylate (PMMA) which completely changed the picture of modern prosthetic dentistry.

Acrylic resin is traditionally polymerized with a water bath method, but microwave energy polymerization, as first reported by Nishii, is an alternative method.^[1] The advantages of polymerizing denture base resin by microwave energy are manifold and include faster polymerization thus reducing the time, a cleaner processing method, and superior adaptation of the denture base to the dental cast.^[2] Although most of the physical properties of denture base resin polymerized by microwave energy proved are similar to resins polymerized by the conventional heat method, the occurrence of porosity when cured by microwave technique has been reported.^[3]

Another matter of concern is a need for effective broad-spectrum antimicrobial resin materials in dentistry and medicine. In dentistry, 50% of patients who wear complete or partial dentures experience problems with stomatitis. In medicine, there is a 1–3% rate of infection after orthopedic surgery and a 5% rate of infection when PMMA was used in cranioplasty despite attempts to create a sterile environment.^[4] Unfortunately, current standards of treatment such as the use of antimicrobial mouthwashes, proper tooth-brushing technique, and the use of prophylactic systemic antibiotics have limited success or side-effects due to problems with patient compliance and the development of antibiotic-resistant strains of bacteria. Thus, a broad-spectrum antimicrobial resin is needed.

Antimicrobial zeolites have been incorporated to serve such a purpose. Zeolites are aluminum silicate crystalline structures that have void spaces measuring 3–10 angstroms in their structure. Antimicrobial cations, such as silver and zinc, may be added to these zeolites which get incorporated into these void spaces and can be exchanged with other cations from the environment. As this ion availability occurs, the free cations come into contact with the environmental microorganisms, suppressing their development by inactivating vital microbial enzymes, interrupting RNA replication and blocking their respiration by an oxidative process.^[5]

This study aims to evaluate the effect of microwave-polymerization technique and the addition of antibacterial zeolites on conventional heat cured denture base resin for the development of a denture base resin with favorable properties for successful and long-term clinical use.

MATERIALS AND METHODS

This study was performed to evaluate the occurrence of porosity in conventional and microwave cured denture base resin along with the addition of antibacterial agent. Thus, the experimental design included three experimental groups and one control group consisting of heat-polymerized specimens. The groups included:

- A – Control group.
- B – Microwave cured denture base resin specimens.
- C – Conventionally cured denture base resin incorporated with antibacterial zeolites.
- D – Microwave cured denture base resin incorporated with antibacterial zeolites.

The antibacterial agent used in the study was IRGAGUARD B 5000 (Ciba India Pvt Ltd.) [Figure 1]. It is an inorganic silver zeolite based antimicrobial which prevents the growth of bacteria, mold, and yeast on plastic surfaces. Zeolites are crystalline aluminosilicates with fully cross-linked open framework structures. The framework has a negative charge, which is balanced by cations such as sodium, silver, etc. These cations are mobile and exchangeable.

Specimen fabrication

Eighty rectangular acrylic resin specimens (65 mm × 40 mm × 5 mm) were fabricated according to ADA specification number 12.^[6] The samples were prepared and divided into four groups, consisting of twenty specimens each categorized into one control group and three experimental groups. Wax patterns of the specimens were fabricated using a three piece standardized mold [Figure 2].

Processing of specimens using conventional heat cure method

The wax patterns were invested in brass flasks using dental stone. Conventional heat-cure acrylic resin (Trevalon HI, Dentsply

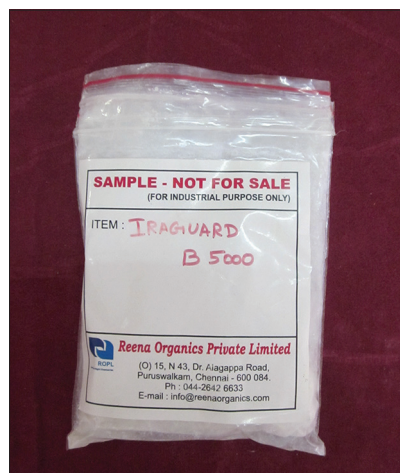


Figure 1: Silver zinc zeolite: Antimicrobial agent

India Private Limited. Batch No: TH70102) available as polymer (powder form) and monomer (liquid form) was mixed in a porcelain jar according to manufacturer's instructions. The mix was allowed to remain for about 10 min till the dough stage was reached. At this stage, the material was kneaded thoroughly and packed into the mold spaces in the flasks. The flask assembly was then reassembled, placed into a bench press and trial closure was done to about 1500 psi to allow application of uniform pressure and permit removal of flash. Following this final closure was done at 3500 psi. The flask was allowed to bench cure for 1 h. Then the flask was immersed in a water bath in an acrylyzer and curing was done at 74°C for 2 h followed by 100°C for 1 h. After the curing cycle is complete the flask was removed from the water bath and bench cooling was done overnight at room temperature before deflasking.^[7,8]

Processing of specimens using microwave method

Curing of specimens by the microwave technique was done in special fiber reinforced plastic flasks specifically designed for microwave use with three nuts provided at the ends [Figure 3]. Polymer and monomer were mixed in the same ratio in a porcelain jar. When dough stage was reached, the mixture was kneaded well and the flask was packed. Trial closure was done using a polyethylene sheet and the flash was removed. Final closure was done and bench curing was done for 1 h.

Curing was done by placing the flask on the rotating turntable of the microwave oven (Whirlpool India Pvt Ltd.). The recommended polymerization method of curing acrylic was applied for 3 min at 500 W.^[2,9]

Retrieval of the test specimens

After complete cooling, the test specimens were carefully retrieved. The excess resin was trimmed from all specimens with a bur. Afterward, each specimen was finished using 400-grit wet/dry sandpaper [Figure 4]. Specimens whichever were unsatisfactory are discarded and remade. The finished specimens were numbered and stored in distilled water at $37 \pm 1^\circ\text{C}$ in an incubator for 48 h.

The finished specimens were marked with an indelible pen using the following code:

- HC – Group A: Conventional Heat cured specimens
- MC – Group B: Microwave cured specimens
- HC + AB – Group C: Heat cured specimens incorporated with an antibacterial agent
- MC + AB – Group D: Microwave cured specimens incorporated with an antibacterial agent.

Porosity analysis

Before testing, the specimens were dried in a desiccator containing silica. Processed specimens were initially weighed

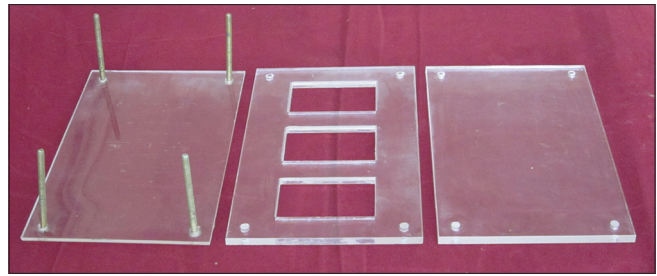


Figure 2: The three piece standardized mold

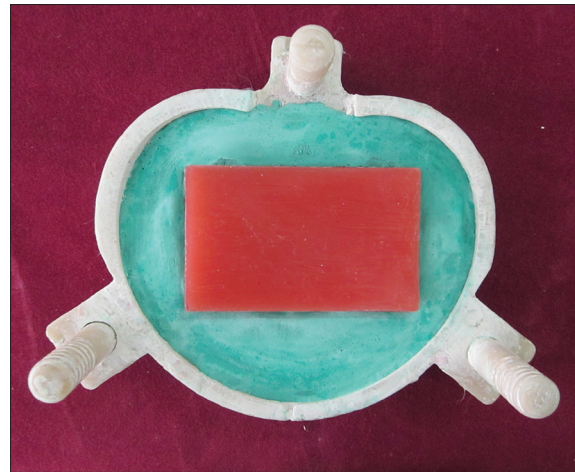


Figure 3: Investing of the wax pattern in special fiber reinforced flasks for microwave use

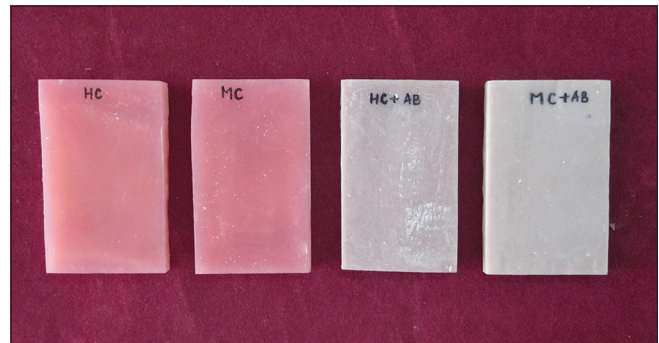


Figure 4: Finished specimens

daily to 0.0001 g with an analytical balance, until a constant weight was achieved [Figure 5]. Weights of all specimens equalized after approximately 7 days. Afterward, the specimen groups were immersed in distilled water at 37°C and weighed at regular intervals until a constant weight was reached [Figure 6]. Again, the weights of all specimens equalized after approximately 7 days.

Each specimen was weighed in air and in water to calculate percent mean porosity. The absolute density of acrylic resin was used to calculate the percent mean porosity by use of the following equations:^[2]

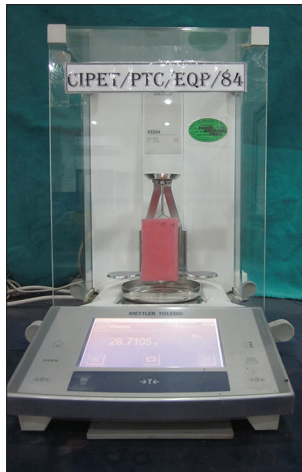


Figure 5: Weighing of specimen in air on an analytical balance

$$W_a = g (d_r - d_a) (V_{sp} - V_{ip}) \quad (1)$$

$$W_w = g (d_r - d_w) (V_{sp} - V_{ip}) + (d_a - d_w) V_{ip} \quad (2)$$

$$\text{Percentage of porosity} = V_{ip}/V_{sp} \times 100 \quad (3)$$

Where W_a = specimen weight in air;

W_w = specimen weight in water;

g = gravitational constant;

d_r = density of acrylic resin;

d_a = density of the air;

d_w = density of water;

V_{sp} = specimen volume, and

V_{ip} = internal porosity volume.

In the first equation, specimen volume minus volume of internal porosity was determined using the following known values: $D_r = 1.1986 \pm 0.01 \text{ g/mL}$, $d_a = 1.23 \text{ kg/m}^3$, $d_w = 1000 \text{ kg/m}^3$, and $g = 9.8066 \text{ m/s}^2$. Having solved the first equation for specimen volume minus volume of internal porosity, this value was used in the second equation, along with W_w measured, to determine the volume of internal porosity. With known values for specimen volume minus volume of internal porosity, the specimen volume could be calculated, divided into the volume of internal porosity, and multiplied by 100 to produce total percent porosity value for each specimen (third equation).

The results were tabulated, subjected to statistical analysis and compared.

RESULTS

The mean values and standard deviations of the specimen weight in air, specimen weight in water, volume of specimen, volume of internal porosity, and percentage porosity for the different groups are listed in Table I.



Figure 6: Weighing of specimen in water on an analytical balance

Table 1: Mean of percentage porosity in different groups (%)

Group	Number of specimens	Mean	SD	SE
A	20	0.9555	0.05586	0.01249
B	20	0.9590	0.08019	0.01793
C	20	0.9630	0.07981	0.01785
D	20	0.9695	0.08287	0.01853
Total	80	0.9618	0.07422	0.00830
<i>F</i>	0.127			
<i>df</i>	3			
<i>P</i>	0.944 (NS)			

NS: Not significant, SD: Standard deviation, SE: Standard error

The results show that there was no significant difference in the percent porosity of the control group and the experimental groups, that is, the use of microwave processing and addition of antimicrobial zeolites showed similar porosity levels as conventional heat cured denture base resin specimens.

DISCUSSION

Polymethyl methacrylate is the most popular dental material used in the construction of partial and complete removable dental prostheses. Introduced in 1936, acrylic resin replaced vulcanite and became the staple material for the fabrication of removable dentures.^[10] The high demand and virtue of this material include its high esthetic value, cost effectiveness and ease of manipulation. However acrylic resins do have their own share of shortcomings such as dimensional instability, residual monomer content, weak strength, water absorption, and color instability thus leading to the conclusion that acrylic resin is by far the most popular denture base material but may still not be the most ideal one. Further research and experiment have led to the improvement in its physical and mechanical properties, handling characteristics and working properties by the introduction of techniques such as microwave processing, light curing, etc.

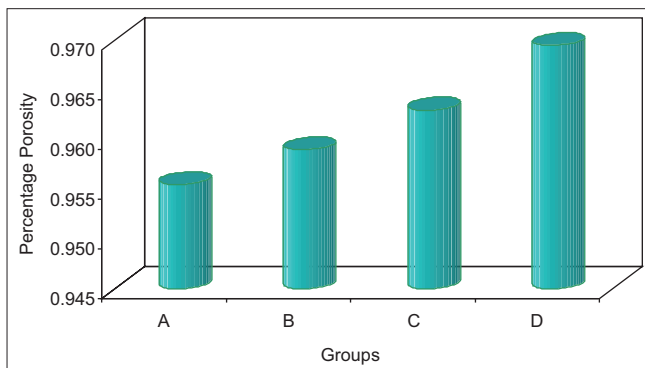
Porosity has been attributed to a variety of factors that include the following: Air entrapped during mixing, monomer contraction during polymerization, monomer vaporization associated with the exothermic reaction, and the presence of residual monomer. Other authors demonstrated that insufficient mixing of monomer and polymer, processing temperatures higher than 74°C, packing of the mold, and inadequate compression on the flask may cause porosity in denture base resin.^[2,11,12]

The comparison of the mean values of percentage porosity showed that the highest value was recorded for group D followed by group C, then group B and the minimum values were obtained for control group A. The mean values were analyzed by ANOVA and it was found that the results were insignificant ($P = 0.944$). The results obtained were in accordance with previous studies conducted^[2,3] [Table I and Graph 1].

The American Dental Association's specification for the porosity of denture base polymers states "there shall be no bubbles or voids when viewed without magnification."^[6] The samples from groups A through D showed no internal or external porosity when viewed without magnification. The percentage porosity of the specimens was well below 11%, thus occurring in accordance to studies conducted by Jerolimov *et al.*^[13]

This study evaluated the occurrence of porosity in denture base resin on addition of antimicrobial agent. The results showed that the addition of 2.5% silver zeolite to PMMA did not result in internal or external porosity. Previous studies have proved the antibacterial and mechanical properties of zeolite added denture resin, the present study confirmed that incorporation of zeolites did not result in porosity and so could be potentially used for the prevention of oral candidiasis in complete denture wearers.

Conventional acrylic resin polymerized in a microwave did not exhibit significant porosity, so it was clinically acceptable;



Graph 1: Comparison of percentage porosity of different groups

hence, it can be used for curing dentures without affecting its mechanical property like surface porosity.

On comparison of percentage porosity between the conventional denture base resin and the microwave cured denture base resin, it was found that that the microwave cured specimens showed marginally more porosity than the control group. However, the results obtained were insignificant and in accordance to studies conducted by Compagnoni *et al.*^[2] Previous studies conducted by Gay and King,^[14] Reitz *et al.*,^[15] Huggett^[16] showed that specimen thickness more than 3 mm resulted in significant porosity, however in this study specimens of thickness 5 mm did not show presence of any significant porosity on curing by microwave technique.

The specimens of different groups cured by the same technique such as group A and C (conventional water bath technique), and group B and D (microwave technique) did not show any difference in the values of porosity suggesting that that the addition of silver zeolite did not interfere with the polymerization procedure of PMMA and also its properties.

The percentage porosity of specimens of group C and D, conventional heat cured denture base resin incorporated with antibacterial zeolite and microwave cured denture base resin incorporated with antibacterial zeolite was compared. It was found that the difference in porosity was insignificant leading to the conclusion that the addition of zeolite did not result in significant porosity when cured by any of the two techniques.

On the basis of the results obtained, it can be concluded that the occurrence of porosity is minimal in denture base resin cured by water bath technique or microwave technique and that microwave processing is a viable alternative to conventional water bath curing as it saves time and is a cleaner and neater option. Furthermore, the addition of antimicrobial agent silver zeolite did not result in the occurrence of internal or external porosity and so this technique can safely be applied to the production of denture bases.

CONCLUSION

This study evaluated and compared the occurrence of porosity in microwave cured and conventional heat cured denture base resin and analyzed effect of addition of antimicrobial zeolite on porosity of denture base resin.

The following conclusions were drawn:

- The percentage porosity in microwave curing of conventional heat cured denture base resin was insignificant
- The difference in mean porosity of conventional and microwave cured denture base specimens was insignificant.

The porosity found in the microwave-polymerized denture base resin tested was similar in porosity to the heat-polymerized resin tested

- The addition of antimicrobial agent in conventional heat cured denture base resin did not result in significant porosity and hence can be used for imparting effective antimicrobial properties to dentures
- The use of microwave processing for polymerization of zeolite incorporated specimens resulted in the highest porosity, but the difference was insignificant
- Thus, microwave processing of conventional denture base resin is a viable option as it is a faster, cleaner and less cumbersome procedure. It also has advantages of excellent dimensional accuracy without porosity and with hardness.

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