Biological and chemophysical features of specially designed microwave-cured acrylic denture resin

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Background/aim

Assortment of denture-based materials and their various curing methods have a great impact on their physical and biological properties. However, esthetics is the most significant parameter in prosthodontics, which is highly deteriorated by water sorption, solubility, and porosity. Moreover, porosity has a great effect on both bacterial and fungus colonization on its surface. This study aimed to assess and compare some physical and biological properties of both heat-cured and microwave-cured acrylic denture-based resins.

Patients and methods

This study was divided into two parts, *in vitro* and *in vivo* parts. The heat-cured and microwave-cured acrylic resin materials were used. Both were utilized for specimens' fabrication in different dimensions according to ADA specifications to assess their physical and biological criteria. Stereo light microscope aided in determining porosity, while both water sorption and solubility were calibrated by employing an electronic-balance device, besides a specific formula for every test individually. In addition, complete dentures were fabricated for 12 edentulous patients from both materials (n=6). *Candida albicans* colonization was assessed by employing both chromogenic candida agar and laboratory-incubator device.

Results

The microwave-cured acrylic denture resin exhibited the lower significant mean value than the conventional heat-cured one in water sorption, corrected water sorption and porosity tests as P value more than or equal to 0.05. Furthermore, it had a significant lower mean value in *C. albicans* colonization during all visits as P value less than 0.05.

Conclusion

The microwave-cured acrylic resin proved to be better as compared with conventional heat-cured denture resin a regarding porosity, water sorption, and solubility, and it had the least affinity to *C. albicans* colonization.

Keywords:
acrylic resin, *Candida albicans*, heat-cured, microwave, porosity, water solubility, water sorption

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Introduction

Denture base is that part of the denture that rests on the foundation areas and to which teeth, backing, and retentive assemblies are added to restore full dentition and the accompanying anatomy of both mandible and maxilla. Moreover, retaining tissue's bulk and appearance and improving masticatory performance along by replacing the missing alveolar tissues, as well as properly redistributing the various occlusal forces along the entire denture bases, are its auxiliary roles [1,2].

Two basic denture-based forms are available and are classified according to their material into metallic (cobalt–chromium and nickel–chromium alloys) and nonmetallic (acrylic resin).

Nevertheless, although heat-cured acrylic resin is the ultimate utilized denture-based material, it cannot initiate the additional polymerization reaction without employing the thermal energy. Thus, a short or long round of water bath is the mandatory power for polymerization of heat-activated PMMA [3].

Moreover, nontoxicity, insolubility, reasonable shelf lifetime, effortless processing, possibility of repair, good esthetics, and reasonable prices are additional criteria for the cured acrylic resin denture-based materials. However, its notable residual monomer content that causes tissue irritation and ends with hypersensitivity, dimensional instability, which is either due to water sorption and solubility or polymerization shrinkage, which affects the material's durability, are few of its drawbacks [4,5].

In addition to possible porosity that usually affects both esthetics and mechanical criteria, microorganisms' sheltering and fluids' confinement. Accordingly, an introductory stage for microbial settlement takes place by its adherence into dentures' pores, which greatly affects patient's general health. Although the availability of a variety of denture detergents, yet currently no single one is competent in either abating or diminishing microorganisms from denture surfaces [6,7].

It is to be mentioned that about 65% of denture wearers are considered as denture stomatitis' patients due to *Candida albicans*' colonization onto denture's surfaces. Although both systemic and local antifungal medications are employed for denture stomatitis, yet it does not prevent its recurrence. Thus, attaining a hygienic, smooth, polishable, and a superiorly esthetic surface reveals the importance of porosity minimization [7].

The utilization of microwave curing of resin has been claimed by alteration in some of its specs and features. Modification of this resin's liquid (monomer) contents to be specially used for microwave curing, as well as modification of the energy applied for this resin's polymerization from microwave into dielectric heat that rapidly impacts the temperature, both interiorly and exteriorly, are good modules for that improvement [8].

Furthermore, using a metal-free flask profoundly enduring compression of packing pressure and allowed fabrication of microwave-translucent material such as permanent glass, communal resins, or superiorly impeded ceramics. A new artificial and commercially achievable model is the light fiber-reinforced flask [8,9].

Adaptation improvement of the processed material is achieved by employing the microwave radiation in processing of microwave acrylic denture resin. Furthermore, little residual monomer that may affect both physical and mechanical properties, dimensional stability, and thermal effect, as compared with short curing time as the denture base, which can be totally polymerized within 3 min, are auxiliary qualities [10,11].

Water sorption and solubility are an example for the vital physical properties that are of utmost importance in the clinical success of denture-based materials. As methmethacrylate monomer, a solvable material when positioned in a hydrous environment, the leakage of unreacted monomer may occur intra-orally. Accordingly, a noteworthy result takes place on both the polymer's mechanical properties and dimensional stability [12].

Furthermore, it is well known according to ADA specification no. 12 for denture-based polymers that a denture plastic should have a water-sorption value of not more than 0.8 mg/cm^2. However, denture plastics of the same nature varied greatly regarding water uptake due to the presence of additives, different curing methods, time, and utilized temperature [13–15].

The purpose of this study was to assess and compare some physical and biological properties of both conventional heat-cured and specially designed microwave-cured acrylic denture-based resins using laboratory and clinical testing methods.

Patients and methods

Study design

This study was divided into two parts. The first part (A) involved the laboratory testing (*in vitro* study), while the second part (B) involved the clinical application (*in vivo* study). The laboratory testing was performed on fabricated samples to evaluate the physical properties (porosity, water sorption, and solubility). While the clinical testing was performed on patients using complete dentures to evaluate *C. albicans* colonization.

Ethical approval

This study was carried out in accordance with the principles of the Declaration of Helsinki in 1975, and all patients were informed about the practical steps of this study and signed written approval consent. The ethical approval was obtained from the Medical Research Ethical Committee (MREC) of National Research Centre (NRC), with approval no. 13142.

Sample-size calculation

Laboratory evaluation

Sample size of *in vitro* study was calculated, depending on a previous study of Singh *et al.* [16] using PS power software. According to this study, the response within each patient group was normally distributed with standard deviation 0.29. If the true difference in the experimental and control means is 0.41, minimally the study needed nine patients in each group, *Clinical evaluation*

While in the *in vivo* study, sample size was calculated, depending on a previous study of Hanafy and Lebshtien [17]. According to this study, the response within each patient group was normally distributed with SD 11. If the true difference in the experimental and control means is 4.5, minimally the study needed four patients in each group to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability. Sample size increased to six per group to compensate 20% dropout (power) 0.8. The type-I error probability associated with this test of this null hypothesis is 0.05.

Materials

Two different types of commercially available acrylic resin denture-bases materials were used in this study. Conventional heat-cured acrylic resin (Acrostone; Acrostone Dental Factory – industrial zone – Salam city A.R.E-WHW Plastic England) and microwave-cured acrylic resin (Protechno; Poligono Emporda Internacional, Garrotaxa, Vilamalla Girona, Spain); group I (Heat Cure A.R.) and group II (Microwave Cure A.R.). Moreover, each cluster was further divided into two subgroups termed as subgroup I.A and subgroup I.B, which were employed for porosity assessment. While subgroup II.A and subgroup II.B were utilized for testing both water sorption and solubility testing.

Methods

A. In vitro study

The physical criteria examined were porosity, water sorption, solubility, and corrected water sorption.

A total number of 36 specimens were fabricated as the following: 18 rectangular-shaped specimens were fabricated using metal patterns (65 mm×10 mm×2.5 mm, length, width, and thickness, respectively, according to ADA specification no. 12) for both subgroup I.A and subgroup I.B (n=9) used for assessing porosity. Additionally, a total number of 18 metal disc specimens were fabricated utilizing metal patterns (50 mm×0.05 mm, diameter and thickness, respectively, according to ADA specification no. 12) for both subgroup II.A and subgroup II.B (n=9) employed for testing both water sorption and solubility and corrected water sorption.

Specimens' fabrication

Conventional metal flask was employed to acquire molds of conventional heat-cured acrylic resin, while a special microwave plastic flask (Tecno-Flask, Protechno, Can Viloca, Spain) was utilized with the microwave one. The inferior section of the dental flask was filled with dental plaster (Elite Rock Stone, Zhermack Clinical, Italy), which was mixed according to the manufacturer's guidelines (i.e. 50 ml/100 g). The metal pattern was coated with the separating medium (Acrostone, Egypt), then a layer of plaster mix was coated on metal pattern. Sequential to plaster setting (30 min.), both the plaster and metal patterns were coated with a separating medium and another layer of plaster was poured into the superior half of the flask with vibration by aid of mold vibrator. The plaster was allowed to harden for 60 min, then finally the flask was unfastened, the metal pattern was detached, and the mold was gained.

Consequently, conventional heat-cured acrylic resin was mixed and packed following the manufacturer's recommendations using stainless-steel spatula. Once approaching the dough stage, it was packed into the plaster mold. Then, the metal flask was compressed with the hydraulic press and placed into the water bath curing unit (water bath curing unit: Type 5518, KaVo EWL, Biberach, Germany) for 30 min at 70°C and extended for an extra 30 min at 100°C for heat curing. Hence, the flask was segregated from the water bath and left to cool at room temperature prior to deflasking, then finishing and polishing of the specimens was made.

The microwave cured denture-based material was then mixed and packed according to the manufacturer's recommendations (a powder ECO-CRYL M: liquid was 2 : 1 by weight). Next to sufficiently achieving a doughy stage, the material was packed into the mold. A special nonmetallic flask as presented in Fig. 1 was compressed beneath manual machinery pressure, then incorporated into the microwave oven for 3 min at 500 W. After curing, the flask was removed from

Figure 1

Microwave plastic flask used in this study.

the microwave and left to chill at room temperature for 30 min, then immersed in cold water for 20 min. Deflasking was performed by gentle mallet blows over the flask's hole and all the specimens were then finished and polished.

Evaluation of porosity, water sorption, solubility, and corrected water sorption

Porosity test was performed by specimens' immersion in a solution of permanent black ink for 30 min, then washed for 10 s, and finally they were dried with an absorbent paper. A surface area of 1 cm^2 was bordered in the center of each specimen and observed under ×40 magnification in a stereo light microscope. The numbers of pores per area were determined for each specimen and an average value was calculated for each group.

Disks were immersed in distilled water at 37±2°C for 7 days and then it was removed from the water, wiped with a clean dry hand towel, until being free from any visible moisture, then waved in air for 15 s, and weighted for 1 min postexclusion from the water. Their weight was regularly calibrated till a constant mass was achieved, indicating water saturation that considered as gained weight of the specimen (m^2). Water sorption of each specimen was assessed by means of a specific formula (Sorption %=(m^2–m^3)/m1×100) and corrected water sorption % also was calculated using the following formula: (corrected water sorption %=weight after 6 weeks of immersion+water solubility–dry weight/dry weight). Moreover, estimation of water solubility took place by utilizing the desiccation technique previously described till attaining a constant terminal weight (m^3). Water solubility of each disk was calibrated employing another specific formula (solubility %=(m^1–m^3)/m^1×100).

In vivo study

In vivo study segment was accomplished by clinical examination of the biological properties (*C. albicans* colonization) after 12 complete denture constructions for both groups (n=6 dentures per group). All patients of the current study were informed about the nature of this research work and their approvals were obtained through a written consent after approval from the Ethics Committee of National Research Center.

Inclusion and exclusion criteria

Inclusion-criteria fulfillment took place by taking full medical and dental histories and intraoral examination. Completely edentulous cooperative 45–60-year aged nonsmoker patients with Angle's class-I maxilla–mandibular relationship, with adequate interarch space and firm sound mucoperiosteal residual alveolar ridges of adequate height and width were selected from the outpatient clinic, Prosthodontics Department, National Research Centre.

Randomization and allocation

Patients included in the current trial were randomly assigned to one of the two experimental groups (simple randomization 1 : 1 ratio) through sequence generation and random allocation. Sequence generation was performed using Rondom.org. online software, while allocation was performed randomly using folded paper and envelope technique. Allocation was done by an assistant supervisor where the code was written in a paper and folded.

Blinding

The statistician was blinded about the type of used material for denture fabrication that the assessed patient received.

Denture construction

Upper and lower complete dentures from both types of acrylic resin denture-based materials were constructed for every patient in the usual manner following the manufacturers' instructions. Patients were randomly divided into two equal groups according to both the denture-based material's type and the curing method used into groups I and II. Group-I patients received complete dentures constructed from conventional heat-cured acrylic resin, while patients who received complete dentures constructed from specially designed microwave-cured acrylic resin were categorized as group II.

Patients' instructions

Patients of both groups were instructed to perform strict oral and denture-hygiene measures. This was performed by dentures' cleaning after every meal only under running water and avoid utilizing any type of denture cleansers, toothpastes, solutions containing phenol, as well as denture adhesives. Additionally, prosthesis removal at night for tissue rest and immersion in a cup of tap water.

Evaluation of *Candida albicans* colonization and follow-up visits

Prior to patients' dismission, denture swabs were obtained from the fitting surface of their maxillary dentures to detect the presence or absence of *C. albicans* and counting it if present. Then, swabs were taken during the follow-up period after denture delivery at 2 weeks, 1, 2, and 3 months consequently.

Swabs were obtained by vigorous rubbing of all the fitting surfaces of the maxillary dentures by using sterile cotton-tipped wooden swab for each patient for 30 s. to facilitate *C. albicans*' isolation. The swab was inoculated immediately in a sterile glass tube containing 1 ml of sterile saline and transferred into a dry container to the laboratory within 1 h. The sample was then plated on the Chromogenic agar medium. The plates were placed in a special incubator (VWR Shel-Labs 1530 Lab Incubator, China) at 37°C, after 48 h of incubation period, the dishes were taken out from the incubator and were observed for light-green colonies with naked eye resembling *C. albicans* colonies.

Chromogenic agar preparation

Chromogenic agar media for identification of *C. albicans* was prepared by both fabricating and proper mixing of a suspension 45.9 g of the medium (Hichrome candida differentiation agar, –India) in 1 l of distilled water and dissolving it by heating with frequent agitation. This was then boiled for 1 min, until complete dissolution and dispensation into Petri dishes were made. Then the prepared medium was homogeneous, free-flowing, and stored at 8–15°C, and the color was clear amber and slightly opalescent.

Statistical analysis

Statistical analysis was performed with SPSS 20 (Statistical Package for Social Science) and Microsoft Excel 2010. Data were presented as means and SD values. Data were explored for normality by using Shapiro–Wilk and Kolmogorov–Smirnov normality test, which revealed that all data are parametric data (P>0.05). Accordingly, comparison between two groups was performed by using independent t test, while comparison between different follow-up periods was performed using repetitive one-way analysis of variance (ANOVA) test followed by Tukey's post-hoc test for multiple comparisons.

Results

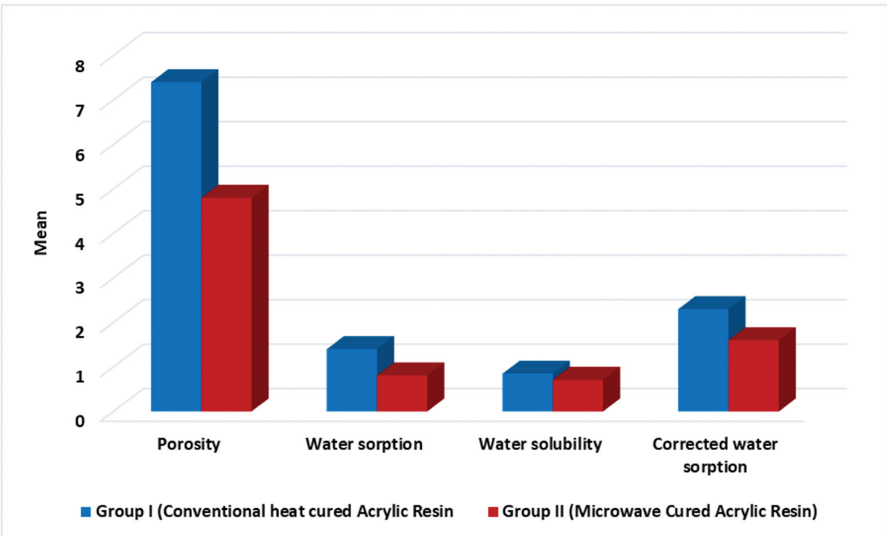
Regarding *in vitro* study, Student's t test was performed to compare between both groups and revealed that group I (conventional heat-cured acrylic resin) was significantly (P<0.05) higher than group II (microwave-cured acrylic resin) in porosity, water sorption, and corrected water sorption, while in water solubility, it was insignificantly lower at P value more than 0.05, as presented in Table 1 and Fig. 2.

Table 1 Porosity, water sorption, water solubility and corrected water sorption regarding group I (conventional heat cured acrylic resin) and group II (microwave cured acrylic resin)

Physical property	Group I (conventional heat-cured acrylic resin)	Group II (microwave-cured acrylic resin)	*P* value
Porosity	7.4±1.01	4.8±1.6	0.0009*
Water sorption	1.4±0.77	0.81±0.32	0.03*
Water solubility	0.85±0.50	0.71±0.32	0.53
Corrected water sorption	2.3±1.55	1.6±0.64	0.002*

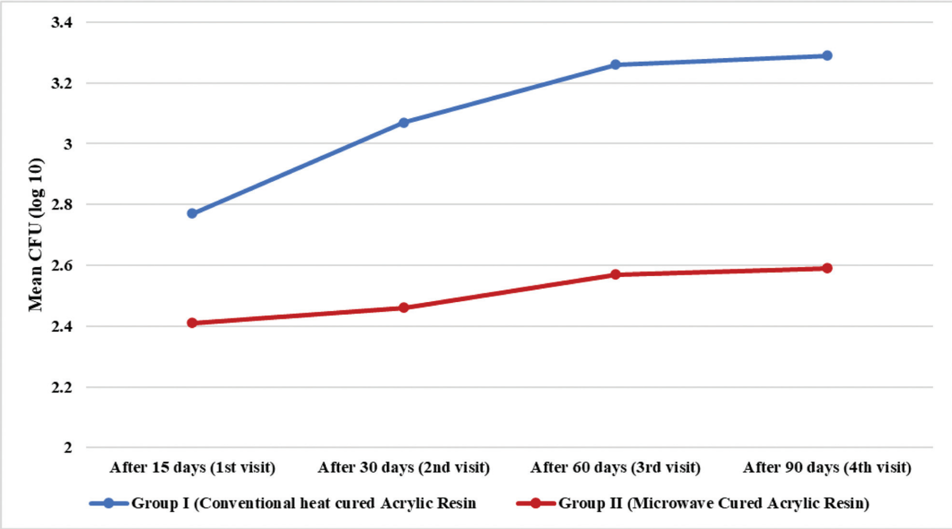
All data are expressed as mean±SD. *Significant difference as *P* value less than or equal to 0.05 using Student's *t* test.

Figure 2



Bar chart represents porosity, water sorption, water solubility, and corrected water sorption of both group I and group II.

Figure 3



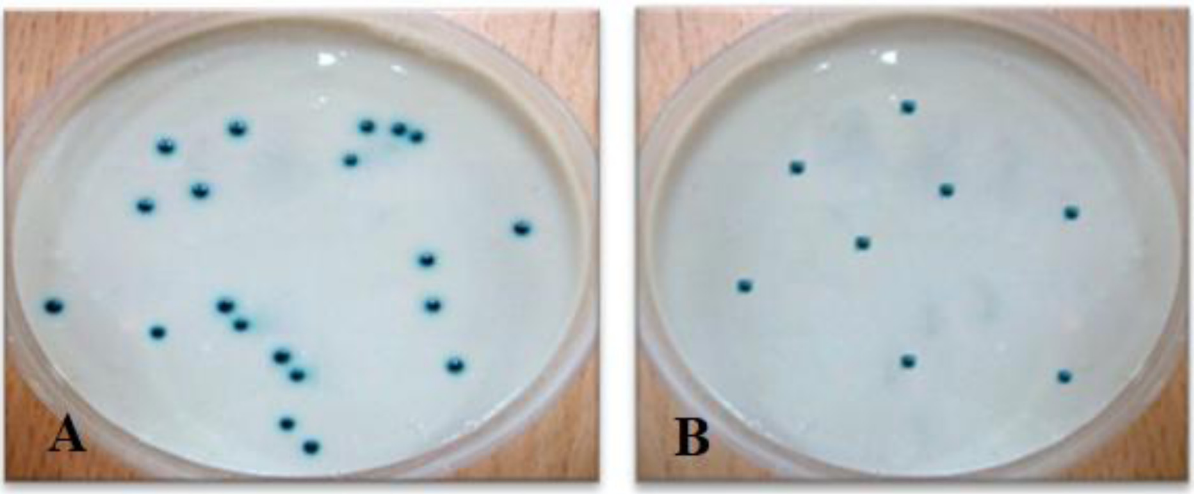
Line chart represents *Candida albicans* colonization in both group I and II during all visits.

Table 2 ***Candida albicans*** **colonization, in group I and group II after 15-, 30-, 60-, and 90-day visits**

	Group I (conventional heat-cured acrylic resin)	Group II (microwave-cured acrylic resin)	*P* value
After 15 days (1st visit)	2.77±0.15[a]	2.41±0.23[a]	0.008*
After 30 days (2nd visit)	3.07±0.1[b]	2.46±0.18[a]	0.0001*
After 60 days (3rd visit)	3.26±0.16[b]	2.57±0.12[a]	0.0001*
After 90 days (4th visit)	3.29±0.24[b]	2.59±0.15[a]	0.0001*
P value	0.01+	0.25	

All data are expressed as mean±SD. +Means with different superscript letter (a, b) are significant different at *P* value less than 0.05, using one way analysis of variance test. *Significant difference as *P* value less than 0.05, using Student *t* test.

Figure 4



Green colonies of *Candida albicans* in chromogenic agar of group I (a) and in group II (b) after the fourth visit.

Regarding *in vivo* study, green colonies of *C. albicans* in Chromogenic agar were obtained in both groups as presented in Fig. 4. In group I, there was a significant increase among different visits by using repetitive one-way ANOVA test, after the first visit, it was 2.77±0.15 and then increased gradually to 3.29±0.24 after the fourth visit. Also, Tukey's post-hoc test for multiple comparisons was performed, which revealed significant difference between colonies after the first visit and all other visits at *P* value less than 0.05, while there was an insignificant difference between all visits, except after the first visit at *P* value more than 0.05, as presented in Table 2 and Fig. 3.

But in group II, *C. albicans* colonization revealed an insignificant difference between different visits at *P* value more than 0.05, using one-way ANOVA. Furthermore, comparison between both groups was performed by using independent *t* test, which revealed that group II was significantly lower than group I during all visits as presented in Table 2. Moreover, illustrated in Fig. 4, line chart showing *C. albicans* colonization along the study-up period.

Discussion

As the curing grade influences the sum of porosity, residual monomer, internal stresses, and dimensional stability of denture-based material, which sequentially primes to specimen's distortion, hence, chilling of the two dissimilar flasks employed in this consideration to room temperature postcuring was obligatory [18,19].

Stereo light microscope aided in sensing acrylic resin specimens' porosity post their immersion in black-ink solution. This procedure was effortless, much favorable, and less devastating than calculating porosity from both specimen weight and mercury porosimetry techniques, respectively [20].

The outcomes of this contemplate revealed that microwave-cured acrylic resin was better than the conventional one regarding porosity. The dissimilar polymerization method justifies this due to the superiority of the microwave's technique over the conventional water bath one. This is referred to the speedy escalation in temperature escorted with nearly identical heating both in and outside of the substance, while the hot-water bath comprises a period for boiling at 100.3°C, then methmethacrylate could be altered into gas-fabricating bubbles trapped in a polymer matrix, and then porosity takes place. Other studies stated that precise temperature prevalence and exact-timing insurance is exceedingly crucial to minimize microwave-energy level and porosity [18,21].

The method recurrently administered for drying and weighing water sorption and solubility samples of the two groups till accomplishing the specimens' constant weight (initial weight) was vastly crucial for standardization, assuring further precise results and following ADA specification no. 12 of denture-based polymers, which documented that water-sorption value of denture plastic ought not to exceed 0.8 mg/cm^2 [22].

Regarding both water sorption and solubility, it was revealed that microwave-cured acrylic resin is better than the conventional one. This might be attributed to the degree and speedy curing of the microwave oven, as well as the minor percentile solubility signifying the diminished release of residual substances as an impact for employing microwave irradiation for polymerization [23–25].

Furthermore, specimens' cooling via water and 24 h of storage of dentures in tap water prior to delivery was mandatory to avoid leaching out of any residual monomer occurred by overheating during finishing and polishing that may induce specimens and dentures' distortion [26,27].

The maxillary dentures' fitting surfaces act as *C. albicans* reservoir due to the irregular surface of the tissue surface of the denture (micropits and microporosities) that harbors microorganisms that are difficult to remove by mechanical methods and facilitate their isolation in the current contemplate by utilizing the simple and competent swabbing technique [28,29].

Growth of *C. albican*s colonies was significant in both groups through the follow-up period. This might be attributed to acrylic resin denture-based derivatives that provoke bacterial imbalance and colonization, subsequently tissue reaction takes place either directly or indirectly. Directly by surrounding denture's fitting-surface porosities and irregularities that support reaping such colonies, while the dropped tissue resistance against infection and the enhanced mucosal epithelium permeability to dissolvable antigens and toxins in ill-fitting dentures and poor denture hygiene are signs for indirect morbidity [30,31].

Additionally, as microwave curing provides several advantages as smoother surfaces of dentures and dimensional accuracy, which eliminate traumatization and inflammation of the mucosa supporting heat-cured dentures during movement through function, accordingly decreased bacterial adherence and advancement of *C. albicans* colonization if compared with conventional resin [32–34].

Conclusion

Within the limitations of this study, it can be concluded that the microwave-cured acrylic resin revealed better properties compared with conventional heat-cured one concerning porosity, water sorption, and solubility. Regarding the biological criteria, although both types of denture-based materials utilized *C. albicans*'s growth, but the microwave-cured acrylic resin dentures had the least affinity to *C. albicans* colonization.

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Conflicts of interest

There are no conflicts of interest.

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