Original Article

The Effect of Microwave Disinfection on Dimensional Stability and Flexural Strength of Acrylic Resins

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Abstract

Background and Aim: Several studies have evaluated the effect of microwave radiation on physical properties of acrylic resins. However, due to the recent introduction of heat-cure and cold-cure acrylic resins into the dental market and rapid popularity of cold-cure resins with less distortion in denture base, the present study sought to assess the effect of microwave disinfection on dimensional stability and flexural strength of two recently introduced heat-cure (Ivoclar) and cold-cure (FuturaGen) acrylic resins.

Materials and Methods: In this laboratory study, acrylic models were fabricated of an edentulous maxillary model using Ivoclar and FuturaGen acrylic resins. Three reference points were marked on the model: two in the back and one in the front of the edentulous arch. These reference points were used for the measurement of dimensional stability in the anteroposterior and cross-arch dimensions. Ten specimens of each acrylic resin were not disinfected. Ten samples were subjected to two 3 min cycles of microwave disinfection with 600 watt power. Distances between the reference points were measured by a Profile Projector. To evaluate flexural strength, a metal mould measuring 64x10x3.3 mm was used for the fabrication of resin specimens. Similar to what was done for dimensional stability testing, 10 specimens of each acrylic resin were not disinfected and 10 other samples were subjected to 3-point bending test after disinfection. Data were compared and statistically analyzed using Mann-Whitney U test.

Results: The mean difference in anteroposterior and cross-arch dimensions revealed that two cycles of microwave disinfection of Ivoclar and FuturaGen acrylic resins did not have a significant effect on their dimensional stability ($p>0.017$). The mean and standard deviation of the flexural strength of FuturaGen acrylic resin before and after disinfection was 76.86±16.80 and 70.18±8.48, respectively. These values for Ivoclar acrylic resin were 85.92±12.23 and 81.91±6.59, respectively. Two cycles of disinfection with microwave did not cause a significant effect on flexural strength of the two understudy acrylic resins. ($p>0.05$)

Conclusion: Two cycles of microwave disinfection had no negative effect on dimensional stability or flexural strength of FuturaGen and Ivoclar acrylic resins.

Key Words: Acrylic resin , disinfection , microwave

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Introduction

Acrylic resins are the most commonly used dental material for fabrication of dentures [1]. However, a main disadvantage of dental prostheses is the rough surface of acrylic resins that facilitates plaque formation on denture surfaces and subsequently increases the risk of accumulation of microorganisms [2, 3].

Studies have shown that various types of oral and non-oral microorganisms are found in denture plaque that are usually associated with local (such as mucosal inflammation)and systemic infections (like urinary infections, conjunctivitis, pneumonia and meningitis) [4, 5]. Microorganisms that adhere to the denture surface are a potential source of infection transmission from patients to the office and dental laboratory personnel. Powell et al. noticed that 67% of all the materials sent from dental offices to dental laboratories were contaminated with opportunistic pathogens [6]. Thus, it is crucial to disinfect dentures in order to prevent cross-contamination and maintain patients' oral and general health [7]. The disinfection method should be able to efficiently deactivate microorganisms without having adverse effects on denture base [4,8, 9]. Previous studies revealed that denture disinfection by immersion in chemical agents such as glutaraldehyde [10], alcohol [11], sodium hypochlorite [12], chlorhexidine digluconate [4, 12] and sodium perborate [4, 13] softens some acrylic resins and decreases their hardness [10, 11, 14].

Some of these agents may penetrate into the denture base. In this case, they are not washed off by rinsing and eventually enter the oral cavity [15, 16].

Several studies have addressed the effect of immersion technique on physical and chemical properties of acrylic resins [10, 11]. A common drawback of using chlorines is denture base discoloration and corrosion of metal frame that are not acceptable by the patients [17].

It has been reported that some disinfection solutions containing sodium hypochlorite and glutaraldehyde have medium to high risk of cytotoxicity [18]. Also, these methods are time consuming and are not suitable for chairside application [19]. Furthermore, it has been shown that these solutions provide a suitable environment for growth of specific types of bacteria [20].

In the recent years, use of electromagnetic waves especially microwaves has been proposed as an effective and successful disinfection method with minimal side effects. Several studies have been conducted on this subject as well [21-23].

Dimensional stability and flexural strength are the two important characteristics of denture base. Some studies have demonstrated that microwave disinfection has no adverse effect on dimensional properties of denture base resins [23-25]; but some others have reported controversial results regarding the effect of microwave disinfection on dimensional stability of resins.

A few studies have demonstrated that denture base acrylic resins well preserve their dimensional stability after microwave disinfection [26-28]; while, some others have reported destructive dimensional changes in acrylic resin following disinfection of denture base with microwave [29-32].

Concerning flexural strength, Pavarina et al. reported that two cycles of microwave disinfection increased the flexural strength of Kooliner and Lucitone 550 acrylic resins but 7 cycles of microwave disinfection decreased the flexural strength of Kooliner and NewTru Liner. Flexural strength of Tokuso Rebase was not affected by microwave radiation and 7 cycles of microwaving caused a significant reduction in flexural strength of Duraliner [33].

Considering the controversial results of previous studies in this respect, it seems that microwave disinfection has different effects on different acrylic resins and these effects should be separately studied for each material. FuturaGen and Ivoclar acrylic resins have been recently introduced into the dental market and no study has evaluated the effect of microwave disinfection on dimensional stability and flexural strength of these two materials. Thus, there was a clear need for further investigation in this respect. The present study sought to compare the flexural strength and dimensional stability of these two new acrylic resins following microwave disinfection.

Materials and Methods

This laboratory study was conducted on two denture base acrylic resins including an autopolymerizing injection acrylic resin (FuturaGen, Schutz Dental GmbH, Germany) and a heat-cure denture base acrylic resin (Ivoclar, Vivadent, USA). To evaluate dimensional stability, an edentulous maxillary model (Typodont) was used. Three cavities including one at the location of central incisor and two at the location of right and left first molars were prepared measuring 4 mm in diameter and 2 mm in depth. These cavities were prepared for use by the Profile Projector for measuring the distances. These cavities comprised the three corners of an equilateral triangle. One side of the triangle (AB) was used for determination of dimensional stability in the anteroposterior dimension and the base of the triangle (BC) was used for determination of dimensional changes in the cross-arch dimension.

All impressions were made using an acrylic custom tray. For custom tray fabrication, two layers of wax were placed over the edentulous ridge. The wax was removed at three points (one in the front and two in the back). These three points were used as stops for impression making to stabilize the tray position and provide similar conditions in terms of tray positioning and thickness of impression material when making repeated impressions. Custom tray acrylic resin was formed over the wax and 24 h later the impressions were made using addition silicone impression material (Elite+HD, Zhermack, Germany) with regular consistency. After 3 min, the impression was removed from the Typodont and poured with dental stone according to the manufacturer's instructions. After adequate mixing, the primary stone, and 15 min later the secondarystonewere poured. After 60 min, the casts were separated from the impressions. Forty master casts were randomly divided into 4 groups and numbered. Two layers of base plate wax were formed on each cast and a silicone index was made with 4 holes for wax overflow. The wax was then removed, the silicone index was filled with melted wax and placed over the cast. After cooling, two groups (n=20) were processed by compression molding and the other two (n=20) by injection molding according to the manufacturer's instructions. Acrylic bases were prepared as such.

Specimens in each group were randomly divided into two equal subgroups:

1.**Group I:** Denture bases made of Ivoclar acrylic resin were immersed in 200 ml of 37°C waterfor 7 days and then subjected to measurement with Profile Projector.

2.**Group F:** Denture bases made of FuturaGen acrylic resin were immersed in 200 ml of 37°C waterfor 7 days and then subjected to measurement with Profile Projector.

3.**Group WI:** Denture bases made of Ivoclar acrylic resin were immersed in 200 ml of 37°C waterfor 7 days and subjected to two cycles of microwave disinfection with 600 watt power at days 3 and 7 each time for 6 min and then underwent measurement with Profile Projector.

4.**Group FW:** Denture bases made of FuturaGen acrylic resin were immersed in 200 ml of 37°C water for 7 days and subjected to two cycles of microwave disinfection with 600 watt power at days 3 and 7 each time for 6 min and then underwent measurement with Profile Projector.

For evaluation of the flexural strength of the two mentioned acrylic resins after microwave disinfection and comparison with the control group, 20 specimens were fabricated of each acrylic resin measuring 64x10x3.3 mm according to ISO1567 standard. To fabricate cold-cure acrylic resin samples, a stainless steel two-part mould was used. After assembly of the parts, the mould provided a space measuring 64x10x3.3 mm. Acrylic powder and liquid were mixed and packed into the mould. A glass slab and a 400g sinker were placed over the mould to pack the acrylic resin and obtain a smooth surface. Time was allowed for polymerization and complete setting of the resin and then the mould was disassembled and the excess materials were removed with a laboratory bur. Specimens were polished with a rubber cap and polishing stones.

For fabrication of heat-cure acrylic resin specimens, amould measuring 64x10x3.3 mm was used. A metal die was fabricated of stainless steel measuring 64x10x3.3 mm. Heavy body putty was packed in the lower part of the flask and the die was pressured into it in a way that it was completely surrounded by the putty. After setting of putty, the die was extracted, acrylic resin was prepared according to the manufacturer's instructions, packed into the mould and cured. Excess materials were removed and the specimen was polished.

Similar to what was done for dimensional stability testing, specimens were randomly divided into groups I, F, I-W and F-W and subjected to flexural strength testing. The 3-point bending test was carried out in Universal Testing Machine (Instron, Zwick/Roell, Zwick GmbH, Germany) with a crosshead speed of 1mm/min and a ball-shapedtip with 1 mm diameter.

Pair-wise comparison of data between the test and control groups was done using Mann Whitney U test. This test adjusted the error rate by using Simple Bonferroni Adjustment. For statistical analysis of dimensional stability and flexural strength $\alpha=0.017$ and $\alpha=0.05$ were considered, respectively.

Results

According to Table 1, in Ivoclar acrylic resin group, the difference in AB and AC (anteroposterior) and BC (cross-arch) dimensions between thecontrol specimens without disinfection and those subjected to microwave disinfection was not statistically significant ($p>0.017$). However, all specimens suffered shrinkage in both dimensions after separation from the cast compared to the original model. The magnitude of this shrinkage was statistically significant ($p<0.017$) (Table 2).

Table 1. Comparison of AB and BC dimensions in Ivoclar (I) group

Dimensions	Difference in mean dimensions (mm)	Standard error	P.v
AB_2, AB_1	-0/16	0/02	<0/001
AB_3, AB_1	-0/16	0/02	<0/001
AB_3, AB_2	0/00	0/01	0/69
BC_2, BC_1	-0/22	0/03	<0/001
BC_3, BC_1	-0/22	0/01	<0/001
BC_3, BC_2	0/01	0/02	0/06

AB_1 and BC_1: Size on the original model
AB_2 and BC_2: Size on acrylic base before disinfection
AB_3 and BC_3: Size on acrylic base after disinfection

In FuturaGen acrylic resin group, all understudy specimens experienced a significant shrinkage in both anteroposterior and cross-arch dimensions after separation from the cast. However, the difference in the mentioned dimensions between controlspecimens without disinfection and those subjected to microwave disinfection was not statistically sig nificant (Table 3). Comparison of AB and BC dimensions between FuturaGen and Ivoclar acrylic resins revealed that the two groups had no

Table 2. Comparison of AB and BC dimensions in FuturaGen (F) group

Dimensions	Difference in mean dimensions (mm)	Standard error	P.v
AB_2, AB_1	-0/22	0/03	<0/001
AB_3, AB_1	-0/20	0/02	<0/001
AB_3, AB_2	0/02	0/01	0/69
BC_2, BC_1	-0/22	0/02	<0/001
BC_3, BC_1	-0/22	0/03	<0/001
BC_3, BC_2	-0/01	0/03	0/06

AB_1 and BC_1: Size on the original model
AB_2 and BC_2: Size on acrylic base before disinfection
AB_3 and BC_3: Size on acrylic base after disinfection

statistically significant difference with each other in terms of dimensional stability before and after microwave disinfection.

In terms of flexural strength, the study results found no significant difference in mean flexural strength of the two acrylic resins before microwave disinfection (P=0.24). No significant difference was detected in flexural strength of FuturaGen acrylic resin in specimens without disinfection and after microwave disinfection (P=0.57). Similarly, no significant difference was found in flexural strength before and after microwave disinfection (P=0.26) but the difference in flexural strength between the two resins after microwave sterilization was statistically significant (P<0.001) and FuturaGen showed a significantly lower flexural strength than the Ivoclar group (Table 4)

Discussion

Many researchers have suggested the use of microwave radiation as a new and cost-effective method for disinfection of dentures. Considering the controversial results of previous studies about the effect of microwave disinfection on acrylic resins, it will be better to study the effect of microwave disinfection on each material separately. Thomas [29] and Pavan [30] reported destructive dimensional changes in acrylic resins after microwave disinfection of denture base. In a study by Seo [39] microwave disinfection increased the shrinkage of denture base acrylic resins. However, in our study, microwave disinfection had no significant effect on dimensional stability of Ivoclar and FuturaGen acrylic resins (P>0.05). Polyzois [28], Parvizi [34] and Keenan [35] reported similar results and no

Table 3. Comparison of flexural strength of FuturaGen acrylic resin (F) between the control and microwave disinfection groups (MPa)

Group	Number	Minimum fracture load	Maximum fracture load	Mean fracture load	Standard deviation	P.v
F	10	58/5	102/00	76/86	16/80	0/57
FW	10	49/90	78/40	70/18	8/48	

Table 4. Comparison of flexural strength of Ivoclar acrylic resin (I) between the control and microwave disinfection groups (MPa)

Group	Number	Minimum fracture load	Maximum fracture load	Mean fracture load	Standard deviation	P.v
F	10	59/70	102/00	85/92	12/23	0/26
FW	10	69/70	94/40	81/91	6/59	

significant changeswere noted in dimensions of specimens before and after microwave disinfection.

In terms of dimensional stability, all specimens experienced a shrinkage immediately after separation from the cast which is due to polymerization shrinkage and is in accord with the results of similar studies. After immer

sion in water and microwave disinfection, some specimens experienced an expansion that may be due to water sorption and some others showed shrinkage that may be attributed to the completion of polymerization process as the result of microwaving. After water storage, specimens irregularly showed insignificant expansion and shrinkage; which is in agreement with the findings of Hugget et al, [36], Lutta et al, [37], Burns et al, [38] and Rohrer et al, [25].

In our study, microwave disinfection had no effect on flexural strength of both acrylic resins. In Polyzois [28] and Consani [27] studies microwave disinfection had no influence on flexural strength of denture base resins.

Pavarina et al, in 2005 reported that two cycles of microwave disinfection increased the flexural strength of Kooliner and Lucitone acrylic resins; but 7 cycles of microwave disinfection reduced the flexural strength of Kooliner and NewTru Liner. Flexural strength of Tokuso Rebase acrylic resin was not influenced by microwave radiation and 7 cycles of microwave irradiation significantly decreased the flexural strength of Duraliner acrylic resin [34]. These conflicting results are probably due to different reactions in different denture base materials. Such different behaviors of acrylic resins indicate the need for separate evaluation of new materials instead of casting the same judgment for all denture base materials.

In the study by Pavarina, two cycles of microwave sterilization increased the flexural strength of chairside reline resins that may be attributed to the completion of polymerization process and reduction of free monomer content which per se has a plasticizing effect [34].

Studies by Vallittu, Kedjaruhe and Urban [40-42] demonstrated that microwave disinfection reduces the amount of residual monomer via two mechanisms:

1.Completion of polymerization process at areas containing free radicals

2.Increasing the movement of monomer molecules and theirimmediate evaporationfrom the acrylic base

These factors can increase the flexural strength and polymerization shrinkage and decrease the dimensional stability of acrylic resins.

Our study demonstrated that the flexural strength of the two acrylic resins was not significantly different before disinfection; which is in agreement with the findings of Farzin et al [43]. However, after microwave disinfection, flexural strength of FuturaGen acrylic resin significantly decreased in comparison to Ivoclar. This finding may be explained by the change in the initiator system and replacement of tertiary amines in FuturaGen acrylic resin with cupper ions and barbituric acid ions. Future studies are required to assess the changes caused by irradiation in this cold-cure acrylic resin.

Conclusion

Microwave disinfection had no negative effect on flexural strength and dimensional stability of FuturaGen and Ivoclar acrylic resins.

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