Influence of Microwave Disinfection on the Dimensional Stability of Denture Reline Polymers

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Abstract

Purpose: The purpose of this study was to evaluate the effect of microwave disinfection (3 minutes at 650 W) on the dimensional stability of hard chairside reline resins (Kooliner, Tokuyama Rebase II, Ufi Gel hard, New Truliner) and one heat-polymerizing denture base resin (Lucitone 550).

Materials and Methods: A split mold with reference points was used to make specimens (50.0-mm diameter, 0.5-mm thick) from each material, divided into five test groups (n = 8). The distances between the points on the mold were measured (gold standard), and compared with those obtained from the specimens after polymerization (baseline readings) after one, two, three, and four cycles of disinfection by microwave irradiation.

Results: ANOVA and Tukey tests ($\alpha = 0.05$) showed that Kooliner was significantly affected by all disinfection cycles ($p < 0.05$) when compared with baseline measurements. New Truliner resin was significantly affected by three and four cycles of microwave disinfection when compared with baseline measurements ($p < 0.05$). For Tokuyama Rebase II, Ufi Gel hard, and Lucitone 550, no significant dimensional changes were found.

Conclusions: Microwave disinfection promoted shrinkage of Kooliner and New Truliner. The dimensional stability of Tokuyama Rebase II, Ufi Gel Hard, and Lucitone 550 was not affected by microwave disinfection.

Microwave energy has been recommended for disinfecting complete dentures to prevent or treat denture stomatitis[1,2] and to control cross-contamination.[1-4] The clinical importance of this procedure is that it can be performed quickly and without the use of toxic and allergenic chemicals; however, microwave disinfection may negatively affect the polymer structure because of the material heating during irradiation of the dentures. The heating of the acrylic resins may enhance further polymerization reaction,[5,6] and shrinkage rather than expansion could be expected.

Some studies have reported that microwave disinfection of denture base acrylic resins and acrylic resin artificial teeth under dry conditions caused small dimensional changes with no clinical significance.[7-9] The effectiveness of microwave disinfection in deactivating potentially pathogenic microorganisms is considerably improved when the specimens are irradiated while immersed in water.[10,11] Neppelenbroek et al[10] verified that contaminated acrylic resin specimens submitted to microwave irradiation at 650 W for 6 minutes in water eliminated pathogenic microorganisms; however, in a previous study in which this protocol was used, microwave disinfection increased the shrinkage of circular specimens made with one denture base and of autopolymerizing reline resins.[12] Another study that analyzed the effect of relining and microwave disinfection on the dimensional stability of denture bases demonstrated increased shrinkage of intact denture bases, as well as those that had been relined.[13]

Different microwave irradiation power/time setting protocols have been used for disinfecting dentures, which may explain the contradictory results of denture resin distortion after microwaving.[7,14,15] In a preliminary study, Mima et al[16] evaluated the effectiveness of different exposure times of microwave

irradiation on the disinfection of a hard chairside reline resin and suggested that 3 minutes at 650 W can be used for acrylic resin sterilization.

Relining of complete dentures is a common procedure to improve the fit of dentures. Autopolymerizing reline acrylic resin has a higher residual monomer content than heat-polymerized acrylic resins used for denture base materials,[17-20] and its presence has an adverse effect on the physical and mechanical properties of the material. During microwave disinfection, the materials are exposed to a high temperature. Acrylic resins may undergo an increase in temperature beyond their glass transition temperature, which could result in distortion of relined denture bases. In addition, no study has investigated the effect of microwave disinfection for 3 minutes at 650 W on the dimensional stability of hard chairside reline resins.

Therefore, the purpose of this study was to evaluate the effect of microwave disinfection (3 minutes at 650 W) on the dimensional stability of hard chairside reline resins. The hypothesis for the current study was that the dimensional stability of relined denture bases would be adversely affected by microwave disinfection.

Materials and methods

A stainless steel split mold (50.0-mm diameter, 0.5-mm thick) with reference points A, B, C, and D was used to fabricate the specimens.[21,22] The simple shape of the specimens permitted examination of the dimensional change of the material itself,[22] and the changes could be attributed to the materials and disinfection method evaluated. The stainless steel mold (Fig 1) was photographed with a digital camera (CyberShot DSC F 828, Sony Corporation of America, New York, NY). The position of the stainless steel mold and the camera was previously fixed at a standard distance. The photographs were obtained with a resolution of eight megapixels. The images were saved in a computer and processed, and the distances measured with ImageLab 2.4 software (Dircom Bio Informatica, Sao Paulo, Brazil). The selection of each reference point in the software was made using zoom, which allows a clear view of the points. Six measurements were made across each dimension (AB and CD) using ImageLab 2.4 software. All standard photographs were taken with a millimeter scale. For each image, the software was calibrated by scale, transforming the distances obtained into millimeters, before the measurements were recorded. These measurements were made by a single calibrated operator so the coefficient of variation of the repeated measures never exceeded 0.04%. These measurements were used to form a gold standard, and the percentage difference of the specimens compared with this gold standard was calculated for each experimental condition.

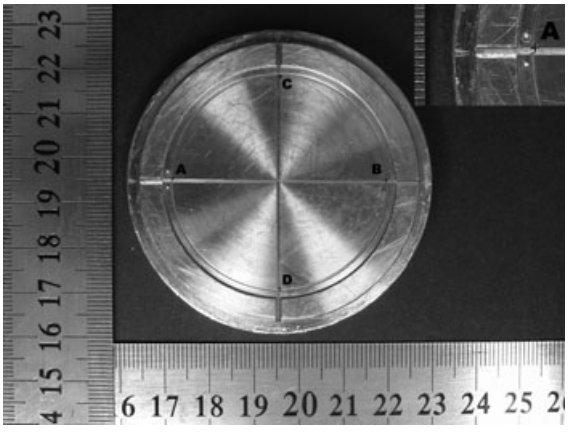

Figure 1 Standard photo of stainless steel split mold (AB = CD = 46.159 mm). The upper right corner shows a zoom on reference point A.

The materials used in this study, together with the manufacturer, composition, polymerization cycles, and polymer-to-monomer mixing proportions are listed in Table 1. The autopolymerizing reline resins were mixed, placed in the stainless steel mold, and polymerized according to the manufacturers' instructions. The denture base acrylic resin specimens were prepared by mixing the powder with the monomer liquid, packing the material into the stainless steel mold, using one trial pack, removing the flash, and polymerizing the specimens using the short cycle recommended by the manufacturer (Table 1). After polymerization, the stainless steel mold was removed from the water bath and bench cooled to room temperature before the specimens were removed.

Thereafter, the autopolymerizing reline resin specimens were ready to be submitted to the experimental conditions. The reline resin specimens were not stored in distilled water to simulate clinical conditions of the direct relining in the mouth. Lucitone 550 acrylic resin specimens were stored in distilled water at 37°C for 50 ± 2 hours, before they could be submitted to the experimental conditions, following American Dental Association specification no. 12.[23]

Eight specimens were made for each material. Before the specimens were submitted to the experimental conditions, standardized photos (Fig 2) were taken, and baseline measurements were recorded. After this, the specimens were subjected to disinfection in a domestic microwave oven (Brastemp da Amazônia S. A., Multibrás S.A. Eletrodomésticos, Manaus, Brazil) calibrated to 650 W for 3 minutes with the specimens immersed in 200 ml of water, once a week (MW1, MW2, MW3, MW4) for 30 days. The specimens were stored in water at 37°C between exposures. Standard photographs and measurements were taken after MW1, MW2, MW3, and MW4. For all specimens, six measurements of each distance were taken after they had been submitted to the experimental conditions, and the arithmetical mean was calculated.

The photographs and measurements of the specimens were obtained in the same manner as was done in the stainless steel mold. The symmetrically located index marks of the stainless steel mold, which were reproduced by the specimens, facilitated the direct comparison of the linear dimensional change in each of the specimens. The difference between the dimensions of each specimen and the dimensions of the stainless steel mold were calculated as percentage of linear dimensional change. The resulting data were subjected to ANOVA and Tukey Honestly Significant Difference post hoc test to determine whether significant differences existed among materials and groups. Statistical analysis was conducted at 95% level of confidence.

Table 1 Materials used to fabricate the specimens

Material	Code	Manufacturer	Composition		Power/liquid ratio (g/ml)	Polymerization cycle
			Powder	Liquid		
Tokuyama Rebase II	T	Tokuyama Dental, Tokyo, Japan	PEMA	1,9-NADMA and 2-AAEMA	2.056/1.0	5.5 minutes at room temperature
Ufi Gel hard	U	Voco, Cuxhaven, Germany	PEMA	1,6-HDMA	2.12/1.2	7 minutes at room temperature
Kooliner	K	GC America, Alsip, IL	PEMA	IBMA	2.1/1.0	10 minutes at room temperature
New Truliner	N	Bosworth, Skokie, IL	PEMA	IBMA DBP	1.34/1.0	20 minutes at room temperature
Lucitone 550	L	Dentsply Indústria e Comércio, Petrópolis, Brazil	PMMA	MMA EDGMA	2.1/1.0	90 minutes at 73°C and 30 minute at 100°C (water bath)

PEMA = poly (ethyl methacrylate); PMMA = poly (methyl methacrylate); 1,9-NADMA = 1,9-nonanediol dimethacrylate; 2-AAEMA = (acetoacetoxy) ethyl methacrylate; 1,6-HDMA = 1,6-hexanediol dimethacrylate; IBMA = isobutyl methacrylate; DBP = di-n-butyl phthalate; MMA = methyl methacrylate; EDGMA = ethylene glycol dimethacrylate.

Results

The mean values (± standard deviations) for the dimensional changes of all materials and experimental conditions are presented in Table 2. The results revealed that Kooliner was significantly affected by all disinfection cycles ($p < 0.05$) when compared with baseline measurements. No statistically significant differences were found among the disinfection cycles ($p > 0.05$). For New Truliner, specimens submitted to three (MW3) and four cycles (MW4) of microwave disinfection showed significantly greater shrinkage than the baseline ($p < 0.05$). Microwave disinfection had no significant effect on the dimensional stability of Tokuyama Rebase II, Ufi Gel hard, and Lucitone 550 ($p > 0.05$).

Comparison among materials revealed that only in cycle 4 (MW4) of microwave disinfection did the Kooliner material show significantly greater dimensional change than the Tokuyama ($p < 0.05$). For other materials, no significant differences were observed irrespective of the microwave disinfection cycle used ($p > 0.05$).

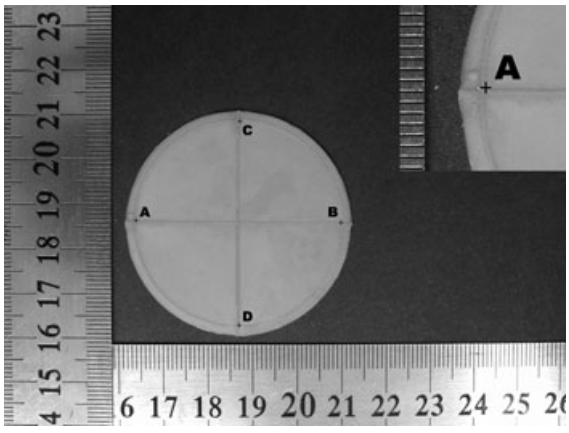

Figure 2 Standard photo of the specimens. The upper right corner shows a zoom on reference point A.

Discussion

In the present study, the influence of a microwave disinfection protocol on the dimensional stability of the reline materials was evaluated. The specimens were disinfected once a week for 30 days, for 3 minutes at 650 W with the specimens immersed in water. The research hypothesis that the dimensional stability of reline and denture base resins would be adversely affected by the microwave disinfection was partially confirmed. Thin specimens (0.5-mm thick), when submitted to the experimental conditions of this study, presented some warping. The warping could have made placement of specimens as parallel as possible to the camera difficult when the photographs were made. This could explain the relatively large standard deviations reported in Table 2.

Microwave disinfection promoted a significant increase in the mean linear dimensional change (shrinkage) for Kooliner and New Truliner. In a previous study, it was shown that Kooliner resin presented a high level of residual monomer.[24] The heating generated by microwave irradiation in an already-polymerized material could leave the resin near its glass transition temperature (Tg), providing more mobility of the monomer molecules still present in the material.[24] As a result, further polymerization may have occurred, which was accompanied by shrinkage, thus increasing the linear dimensional change. It is interesting to note that the shrinkage occurred in the first disinfection (MW1). In subsequent disinfections (MW2, MW3, and MW4) the dimensional changes were similar. One possible explanation for these results could be that the rise in temperature during microwave disinfection may have facilitated the release of residual monomer,[25,26] and further polymerization reaction may have occurred in the first disinfection,[27] thereby reducing the monomer molecules. A direct comparison could not be made with the study of Gonçalves et al[12] because of the

Table 2 Mean values and standard deviations of dimensional change (%)

	Baseline	MW 1	MW 2	MW 3	MW 4
Tokuyama	−0.234 ± 0.138 A[a]	−0.294 ± 0.249 A[a]	−0.290 ± 0.167 A[a]	−0.202 ± 0.176 A[a]	−0.316 ± 0.192 A[a]
Ufi Gel hard	−0.402 ± 0.224 A[a]	−0.447 ± 0.182 A[a]	−0.441 ± 0.185 A[a]	−0.484 ± 0.141 A[a]	−0.415 ± 0.131 AB[a]
Kooliner	−0.196 ± 0.120 A[a]	−0.611 ± 0.268 A[b]	−0.545 ± 0.137 A[b]	−0.504 ± 0.263 A[b]	−0.650 ± 0.237 B[b]
New Truliner	−0.199 ± 0.175 A[a]	−0.425 ± 0.181 A[ab]	−0.378 ± 0.174 A[ab]	−0.503 ± 0.211 A[b]	−0.529 ± 0.164 AB[b]
Lucitone 550	−0.291 ± 0.118 A[a]	−0.372 ± 0.222 A[a]	−0.361 ± 0.186 A[a]	−0.274 ± 0.278 A[a]	−0.434 ± 0.266 AB[a]

Within each row, entries with the same lowercase letter were not significantly different at $p < 0.05$.
Within each column, entries with the same uppercase letter were not significantly different at $p < 0.05$.

different protocols used; however, those authors also verified that two cycles of microwave irradiation for 6 minutes at 650 W resulted in higher shrinkage than that of seven cycles.[12]

New Truliner reline resin was the only material that showed significant linear dimensional change in relation to the baseline when the specimens were submitted to MW3 and MW4. The powder-to-liquid ratio of New Truliner is lower than that of the other materials assessed; therefore, one might expect a dimensional change in the first cycle. However, contrary to expectations, this material presented no significant difference in MW1 and MW2. Despite differences in the microwave irradiation time/power, Seo et al[13] verified further shrinkage with New Truliner material when submitted to one cycle of microwave disinfection. In the present study, the reason for the different behavior of New Truliner may be explained by the greater flexibility of the polymer, due to the presence of the plasticizer di-n-butyl phthalate in the liquid.[18] Therefore, repeated microwave disinfection at 650 W for 3 minutes could have promoted rearrangement of reline chains, leading to dimensional change. Further investigations regarding the effect of microwave disinfection on the degree of conversion of New Truliner and Kooliner resins are needed to explain this behavior.

The dimensional stability of Ufi Gel hard and Tokuyama Rebase II reline resins was not affected by any of the disinfection methods, irrespective of the number of cycles. These findings could be related to the extent of the polymerization reaction. The monomer used in Ufi Gel hard and Tokuyama Rebase II is a dimethacrylate. The presence of a bifunctional monomer might improve the polymerization process, by providing more reactive groups for free radical polymerization. Furthermore, this could be attributed to the highly cross-linked nature of these relines that contain two double bonds, which might have enhanced the polymerization reaction.[12] Thus, Ufi Gel Hard and Tokuyama Rebase II specimens were probably less susceptible to further polymerization and shrinkage during the disinfection methods evaluated. This finding is in agreement with those reported by Seo et al.[13]

The dimensional stability of Lucitone 550 denture base acrylic resin was not affected by microwave irradiation. The results contradict another study that showed increased linear dimensional change for Lucitone 550 after microwave disinfection.[12] The difference in disinfection protocol probably explains the different results.

During microwave disinfection, the water reached its boiling point after approximately 90 seconds of microwave disinfection. It is possible that the higher temperature of the water could have increased the diffusion of remaining residual monomer molecules[26] to the active sites of the polymer chain.[27] This additional polymerization results in high internal stress, making the resin vulnerable to distortion and warpage. According to Azzarri et al,[28] the exposure time appears to be the most relevant factor in achieving the best mechanical performance of the materials. Diminishing the exposure of materials to microwave for 3 minutes at 650 W should promote disinfection without causing dimensional change;[27,29] however, the exposure time of 3 minutes significantly affected the Kooliner material in all disinfection cycles when compared with baseline. Further studies to investigate the relationship between the microwave power and time conditions and their effect on the physicochemical characteristics of the materials evaluated, would help to explain the dimensional change observed in the present study.

When the materials were compared, Kooliner showed significantly greater dimensional change than Tokuyama Rebase II only in cycle 4 of microwave disinfection. These differences can be explained by comparing the composition of their monomer liquids. Tokuyama Rebase II is a cross-linked polymer, while Kooliner contains a monofunctional methacrylate monomer without a cross-linking agent. It is likely that variation in monomer availability from the different autopolymerizing polymers accounted for the diverse results. The presence of cross-linking agents in Tokuyama Rebase II may be an important factor in the dimensional stability observed in the present study.

The results of the present investigation demonstrated that for Tokuyama Rebase II, Ufi Gel hard, and Lucitone 550, exposure to microwave irradiation for 3 minutes at 650 W could be chosen to produce consistent disinfection without any detrimental effect on the materials; however, in denture bases relined with Kooliner and New Truliner, adjustments may be required because warping could cause pressure on the supporting tissues and thus, discomfort to the patient.[30]

Conclusion

Based on the results and limitations of this study, the following conclusions were drawn:

1. Microwave disinfection promoted shrinkage of Kooliner and New Truliner materials.
2. The dimensional stability of Tokuyama Rebase II, Ufi Gel hard, and Lucitone 550 was not affected by microwave disinfection.

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