Linear Dimensional Changes of Denture Base and Hard Chair-Side Reline Resins after Disinfection

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ABSTRACT: *Objectives:* This study evaluated the effect of disinfection by immersion in sodium perborate (50°C/10 min) or microwave irradiation (650 W/6 min) on the linear dimensional change (LDC) of four reline resins (Kooliner-K, New Truliner-N, Tokuso Rebase Fast-T, Ufi Gel Hard-U) and one heat-polymerizing denture base resin (Lucitone 550-L). *Methods:* Specimens (50.0 mm diameter, 0.5 mm thickness) were made using a split mold with reference points, and divided into two controls and four test groups (n = 8). The distances between the points were measured on the mold (baseline readings), and compared to those obtained from the specimens after: polymerization or immersion in water (37°C) for 7 days (controls); 2 or 7 cycles of disinfection by immersion or microwave irradiation. *Results:* The two-way ANOVA and Tukey's test (α = 0.05) showed that microwave disinfection significantly increased the mean LDC of materials L (−1.43%), N (−1.27%) and K (−1.06%). Material N also exhibited a significant increase in LDC after two cycles of chemical disinfection (−0.73%). For U (−0.47%) and T (−0.21%) materials, no significant changes in LDC were found. *Conclusions:* Microwave disinfection increases the shrinkage of materials L, N, and K. The dimensional stability of resins U and T was not affected by the disinfection methods evaluated. © 2006 Wiley Periodicals, Inc. J Appl Polym Sci 102: 1821–1826, 2006

Key words: dental polymers; irradiation; linear

INTRODUCTION

Denture disinfection has been recognized as an essential measure in the prevention of cross-contamination,[1] and should be used in the routine practice for the benefit of patients and dental personnel. A previous clinical study has demonstrated that an infection control protocol, which included scrubbing the dentures with 4% chlorhexidine followed by immersion in sodium perborate solution at 50°C for 10 min, is effective in reducing the microbial growth on dental prostheses.[2] Similarly, microwave irradiation for 6 min in water at 650 W, performed on contaminated hard chair-side reline specimens also proved to completely eliminate potentially pathogenic microorganisms.[3]

Ideally, a disinfection method should be effective without causing a detrimental effect on the acrylic resins used for the fabrication and the relining of denture bases. Preliminary studies have shown that the infection control protocol and microwave disinfection produced no detrimental changes in the transverse strength,[4,5] surface hardness,[6] and bond strength[7] of some denture base and hard reline acrylic resins. However, other properties may be adversely affected by these disinfection methods. Among these properties, the dimensional stability is of utmost importance because it is closely related to the fit of the denture bases to the supporting tissues.[8,9]

Some studies have reported that microwave disinfection of conventional denture base acrylic resins under dry conditions caused small dimensional changes with no clinical significance.[10,11] However, the effectiveness of microwave disinfection in deactivating potentially pathogenic microorganisms is considerably improved when specimens are irradiated while immersed in water.[3,12] The increase in temperature during chemical and microwave disinfection may accelerate the water sorption rate of the acrylic resins,[13] and dimensional changes may occur due to expansion of the polymerized mass.[14] Conversely, the heating of the acrylic resins may enhance further polymerization reaction,[15,16] and shrinkage rather than expansion could be expected. A previous study demonstrated that one hard chairside reline resin showed a significant increase in shrinkage after immersing in water at 55°C,[17] a temperature closed to the one used in the infection control protocol. In the case of microwave irradiation, the water starts to boil (100°C) after ap-

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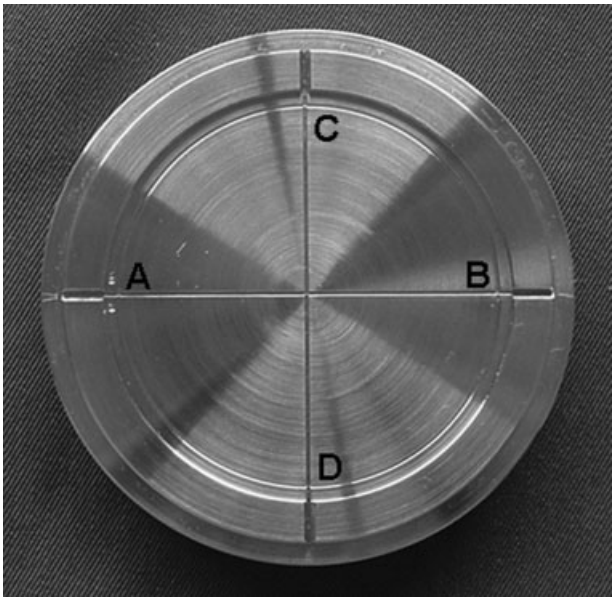

Figure 1 Master die dimensions. AB = CD = 45.736 mm

proximately 1 min and 30 s,[3] and remains at this temperature until the end of the 6 min disinfection time. To which extent the temperatures involved in the disinfection methods could affect the dimensional stability of heat-polymerizing and autopolymerizing acrylic resins has yet to be investigated.

Thus, the hypothesis tested in this study was that the linear dimensional change of four autopolymerizing hard chair-side reline resins and one heat polymerizing denture base acrylic resin would be affected by chemical and microwave disinfection.

MATERIALS AND METHODS

A stainless steel split mold (50.0 mm diameter and 0.5 mm thickness) with reference points A, B, C, and D was used to fabricate the specimens (Fig. 1).[17,18] The simple shape of the specimens permitted examination of the dimensional change of the material itself,[18] and the changes could be attributed to the materials and disinfection methods evaluated. Twelve measurements were made across each dimension (AB and CD) directly from the stainless steel mold with an optical comparator (Profile Projector 6C; Nikon, Tokyo, Japan) to the nearest 0.001 mm. From these measurements, a baseline measurement was calculated (45.736 mm). Verification of the accuracy and repeatability of the measurements was accomplished by performing 12 repeated measurements between the reference points (AB and CD). These measurements were made by a single calibrated operator so that the coefficient of variation of the repeated measures never exceeded 0.04%.

Four hard chairside reline resins and one heat-polymerized denture base conventional acrylic resin were selected for this study. The materials, codes, manufacturers, composition, proportions of powder to liquid, polymerization cycles, and batch numbers are listed in Table I. 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 monomer liquid, packing the material in the stainless steel mold by using one trial pack, removing the flash, and polymerizing using the short cycle recommended by the manufacturer (Table I). Although the manufacturer also recommends a long polymerization cycle (9 h at 73°C), the short cycle was selected for this study because it included a terminal cycle for 30 min at 100°C. This short cycle was found to promote lower residual monomer content in the material Lucitone 550 than the long polymerization cycle.[19] After polymerization,

TABLE I
Materials Used in This Study

Material	Code	Manufacturer	Composition		Powder/liquid ratio (g/mL)	Polymerization cycle	Batch no.
			Powder	Liquid			
Kooliner	K	GC America, Alsip, IL, EUA	PEMA	IBMA	2.1/1.0	10 min at room temperature	0201102
New Truliner	NT	Bosworth, Skokie, IL, EUA	PEMA	IBMA DBP	1.34/1.0	20 min at room temperature	0310–528
Tokuso Rebase Fast	TR	Tokuyama Dental, Tokyo, Japan	PEMA	MAOP 1,6-HDMA	2.056/1.0	5.5 min at room temperature	U570612
Ufi Gel Hard	UGH	Voco, Cuxhaven, Germany	PEMA	1,6-HDMA	2.12/1.2	7 min at room temperature	025292
Lucitone 550	L	Dentsply Indústria e Comércio, Petrópolis, RJ, Brazil	PMMA	MMA EDGMA	2.1/1.0	90 min at 73°C and 30 min at 100°C	Powder, 65173 liquid, 37375

PEMA, poly (ethyl methacrylate); PMMA, poly (methyl methacrylate); IBMA, isobutyl methacrylate; DBP, di-*n*-butyl phthalate; MAOP, β-methacryloyl oxyethyl propionate; 1,6-HDMA, 1,6-hexanediol dimethacrylate; MMA, methyl methacrylate; EDGMA, ethylene glycol dimethacrylate.

TABLE II
The Groups and the Disinfection Methods Used in the Study

Group	Disinfection method
C1 (control 1)	No submission to any disinfection method
C2 (control 2)	Immersed in distilled water at 37°C for 7 days
ICP 2	Disinfected twice using a disinfection control protocol (scrubbing with 4% clorhexidine for 1 min., immersing in 3.8% sodium perborate solution at 50°C for 10 min., and immersing in water for 3 min)
ICP 7	Disinfected seven times using the disinfection control protocol
MW 2	Disinfected twice using microwave disinfection (immersed in 200 ml of water and irradiated with 650 W for 6 min)
MW 7	Disinfected seven times using microwave disinfection

the stainless steel mold was removed from the water bath and bench cooled to room temperature before the specimens were removed.

Forty-eight specimens were made for each material, and divided into two control groups and four test groups of eight specimens each (Table II). The autopolymerizing reline resin specimens were subjected to the experimental conditions immediately after preparation. Before being submitted to the experimental conditions, the Lucitone 550 acrylic resin specimens were stored in distilled water at 37°C for 50 ± 2 h.[20] Specimens from ICP 2 and MW 2 test groups were disinfected twice to simulate when contaminated dentures come from the patient and before being returned to the patient. For test groups three (ICP 7) and four (MW 7), specimens were submitted to a total of seven cycles of disinfection using the infection control protocol or microwave irradiation, respectively. The specimens were disinfected daily for 7 days being stored in water at 37°C between disinfection cycles.[5,7] Daily disinfection was chosen due to the fact that a number of follow-up visits for denture base adjustments may be required after relining. Thus, dentures can be exposed to repeated disinfections during this period. Considering that the number of recall appointments may vary among patients, seven disinfection cycles were chosen randomly and intended to detect any possible cumulative effect of the disinfection methods on the dimensional stability of the materials evaluated.

The symmetrically located index marks of the stainless steel mold, which were reproduced by the specimens, facilitated the direct comparison of the linear dimension change in each of the specimens. Measurements were made on all specimens by the same investigator after they had been submitted to the experimental conditions. The difference between the dimensions of each specimen and the baseline reading on the stainless steel mold was calculated as percentage of linear dimensional change. The resulting data were subjected to two-way analysis of variance (ANOVA) and Tukey Honestly Significant Difference (HSD) *pos hoc* test to determine whether significant differences existed among materials and groups. Statistical analysis was conducted at 95% level of confidence.

RESULTS

The two-way analysis of variance revealed significant ($P < 0.001$) differences in the linear dimensional change for the variables material and group, and their interaction (Table III). The means and standard deviations for linear dimensional change are shown in Table IV. Two and seven cycles of microwave disinfection (groups MW 2 and MW 7, respectively) significantly increased ($P < 0.001$) the mean linear dimensional change of materials Lucitone 550 and New Truliner compared to their respective controls (C1 and C2). For Kooliner material, MW 2 specimens showed significantly higher mean linear dimensional change than control C1 specimens ($P < 0.001$), whereas no significant difference was found between groups MW 7 and C2. For Lucitone 550 specimens, seven cycles of microwave disinfection promoted higher mean linear dimensional change than that of two cycles ($P < 0.001$). For Kooliner material, the mean linear dimensional change of MW 2 specimens was significantly higher than that of MW 7 specimens ($P < 0.001$).

When the specimens were submitted to two cycles of disinfection using the infection control protocol

TABLE III
Results of 2-Way ANOVA

Source of variation	Sum of squares	df	Mean square	*F* value	*P* value
Tested material (M)	6.204	4	1.551	94.08	<0.001
Disinfection method (D)	9.45	5	1.890	114.72	<0.001
M × D	7.6	20	0.380	23.03	<0.001
Error	3.36	210	0.016		
Total	26.614	239			

TABLE IV
Mean Values and Standard Deviations (SD) of Dimensional Change (%)

Material	Disinfection method					
	C1	ICP 2	ICP 7	MW 2	MW 7	C2
Lucitone 550	−0.29AB[a] (0.08)	−0.41 A[a] (0.10)	−0.42 AB[a] (0.14)	−0.98 B[b] (0.15)	−1.42D[c] (0.11)	−0.52 A[a] (0.08)
New Truliner	−0.31AB[a] (0.09)	−0.73 B[c] (0.14)	−0.66 B[bc] (0.16)	−1.27C[d] (0.15)	−1.14C[d] (0.14)	−0.49A[ab] (0.22)
Kooliner	−0.23AB[a] (0.11)	−0.43A[ab] (0.14)	−0.44AB[ab] (0.12)	−1.06B[d] (0.14)	−0.72 B[c] (0.19)	−0.53A[bc] (0.09)
Ufi Gel Hard	−0.47 B[a] (0.07)	−0.3z9 A[a] (0.10)	−0.42 AB[a] (0.15)	−0.60A[a] (0.10)	−0.39A[a] (0.13)	−0.43 A[a] (0.08)
Tokuso Rebase Fast	−0.21 A[a] (0.10)	−0.38 A[a] (0.09)	−0.33 A[a] (0.09)	−0.41A[a] (0.13)	−0.22A[a] (0.11)	−0.32 A[a] (0.09)

Vertically, identical capital letters denotes no significant differences among materials ($P < 0.05$). Horizontally, identical superscripted small letters denote no significant differences among groups ($P < 0.05$). Number in parenthesis = standard deviations.

(ICP 2), only New Truliner material showed a significant higher mean linear dimensional change than that of group C1 ($P < 0.001$). The linear dimensional change of materials Lucitone 550, New Truliner, and Kooliner was not significantly affected by the infection control protocol, regardless of the number of cycles. For materials Ufi Gel Hard and Tokuso Rebase Fast, there were no significant differences among all groups evaluated.

Comparison among materials revealed that for C1 control specimens, the mean linear dimensional change of Ufi Gel Hard material was significantly higher than that of Tokuso Rebase Fast reline resin ($P = 0.023$). However, no significant differences were observed when the mean linear dimensional change of either Ufi Gel Hard or Tokuso Rebase Fast was compared to those of the other materials evaluated. In addition, there were no significant differences between the mean linear dimensional change of Lucitone 550 material and the autopolymerizing reline resins. For group control C2, no significant differences were found among all materials evaluated.

DISCUSSION

The hypothesis tested in the present investigation was accepted because the linear dimensional change of the materials was significantly affected by both disinfection methods evaluated. The size and shape of the specimens used in the present investigation did not simulate the complex form of a denture base, and the change in three dimensions could not be measured. However, the method used is simple, permits accurate measurement of the linear dimensional change of the material itself, and has been previously used to evaluate the dimensional changes of denture base and autopolymerizing reline acrylic resins.[17,18]

Microwave disinfection promoted a significant increase in the mean linear dimensional change (shrinkage) for materials Lucitone 550, New Truliner, and Kooliner. Contrasting results were observed by other investigators, who have found that the dimensional changes of conventional denture base acrylic resins after microwave disinfection were small and probably of no clinical significance.[10,11] In these previous studies,[10,11] however, the acrylic resins were irradiated under dry condition, whereas in the present investigation the materials were disinfected while immersed in water, which started to boil after ~1 min and 30 s. This may have enhanced the diffusion of residual monomer molecules that continue to be present in the polymerized material[21,22] to the active sites of the polymer chain.[23] As a result, further polymerization may have occurred, which was accompanied by shrinkage, thus increasing the linear dimensional change of Lucitone 550, New Truliner, and Kooliner microwaved specimens. Other studies have observed that a significant reduction in the residual monomer content of polymerized acrylic resins can be achieved by an additional heat-cure cycle at 100°C[24] or exposure to microwave irradiation.[16] However, further investigations regarding the effect of microwave disinfection on the degree of conversion of materials Kooliner, New Truliner, and Lucitone 550 are needed to confirm this hypothesis.

The increased linear dimensional change observed for Lucitone 550 after microwave disinfection was not expected since the residual monomer in the heat-polymerized acrylic resins is lower than that of the autopolymerized acrylic resins.[21] These findings can be related to the polymerization cycle used for processing the Lucitone 550 specimens, which included a terminal boil for only 30 min. This short length of time at 100°C probably resulted in a lower degree of conversion of the specimens.[22] During microwave disinfection, a further shrinkage occurred probably as a result of residual monomer conversion into polymer. The additional linear dimensional changes could also be attributed to the release of the stresses incorporated within the Lucitone 550 during processing.[25–27]

For Kooliner material, two cycles of microwave irradiation resulted in higher shrinkage than that of seven cycles. The specimens submitted to seven cycles of microwave disinfection were irradiated daily, being

immersed in water between exposures. Therefore, it could be that the expansion promoted by the water absorbed during this period may have partially compensated any additional shrinkage of Kooliner specimens during repeated microwave disinfection.[14] Lucitone 550 acrylic resin exhibited an opposite behavior, with seven cycles of microwave disinfection producing increased linear shrinkage compared with two cycles. These findings can be related to differences in composition. While Kooliner is a non-*cross*-linked material, Lucitone 550 denture base resin contains a crosslinking agent, which has been found to decrease water sorption.[28]

New Truliner reline resin was the only material that showed significant linear dimensional change, when the specimens were submitted to the infection control protocol (two cycles). Because of its lowest powder to liquid ratio, New Truliner material residual monomer is probably higher than the other materials evaluated.[29] Therefore, it can be hypothesized that heating New Truliner specimens at 50°C soon after polymerization, when the levels of monomer molecules and free radicals are usually high,[15,21,23] may have facilitated the conversion of residual monomer to polymer. As a result, a significant shrinkage occurred.

The dimensional stability of Ufi Gel Hard and Tokuso Rebase Fast reline resins was not affected by any of the disinfection methods, regardless of the number of cycles. These favorable results can be related to the composition of Ufi Gel Hard and Tokuso Rebase Fast materials, which contain high percentage of the crosslinking agent 1,6-hexanediol dimethacrylate in the liquid. The dimethacrylates promote a higher degree of conversion compared to the monofunctional monomers, such as isobutyl methacrylate contained in the liquid of New Truliner and Kooliner reline resins. The presence of crosslinking agent with two double bonds might have enhanced the polymerization reaction of the reline resins Ufi Gel Hard and Tokuso Rebase Fast. In addition, the increased distance between the methacrylate groups in the crosslinking agent 1,6-hexanediol dimethacrylate increases the reactivity of the second double bond, favoring the monomer to polymer conversion.[30] This hypothesis is supported by other studies[19,29] in which Tokuso Rebase Fast and Ufi Gel Hard materials showed residual monomer content considerably low and did not differ significantly from those of the heat-polymerizing acrylic resins investigated. Thus, Ufi Gel Hard and Tokuso Rebase Fast specimens were probably less susceptible to further polymerization and shrinkage during the disinfection methods evaluated.

When the materials were not subjected to the disinfection methods evaluated (control groups), it was observed that the dimensional stability of Lucitone 550 denture base acrylic resin did not differ from that of the autopolymerizing reline resins. In addition, the linear dimensional change values observed for all control specimens were within the range of 0.2%–0.5% usually found during the polymerization of autopolymerizing and heat-polymerizing acrylic resins.[9,26,31] These changes in dimension probably could not be detected by the patient.[32] After microwave disinfection, however, the linear dimensional changes of materials Lucitone 550 and New Truliner (two and seven cycles), and Kooliner (two cycles) significantly increased, with values ranging from −0.98% to −1.43%. Shrinkage of such a degree could probably cause pressure on the supporting tissues and thus discomfort to the patient.[33]

It should be emphasized that the results from the present investigation should be interpreted with caution. The use of simulated relined denture bases and a combination of other measurements, such as the amount of posterior border discrepancy, might be better to reflect the effect of the disinfection methods on the three-dimensional change of the bases, and should be considered in further investigations. Despite these limitations, however, denture bases relined with Ufi Gel Hard and Tokuso Rebase Fast can be expected to exhibit low shrinkage after disinfection.

CONCLUSIONS

Within the limitations of this *in vitro* study, the following were concluded:

There were not apparent important differences in the dimensional stability that arose as a result of chemical disinfection. Conversely, the effect of microwave disinfection was more pronounced and varied among materials.

1. Microwave disinfection promoted a significant increase ($P < 0.001$) in the mean linear dimensional change for materials Lucitone 550, New Truliner and Kooliner; however, for material Kooliner there was no significant difference between the mean linear dimensional change of the specimens irradiated daily and that of the specimens immersed in water only for 7 days ($P > 0.05$).
2. The dimensional stability of the materials evaluated was not significantly affected by disinfection with the infection control protocol ($P > 0.05$), with the exception of material New Truliner, which showed a significant increase in the mean linear dimensional change after two cycles of immersion disinfection ($P < 0.001$).
3. The dimensional stability of materials Tokuso Rebase Fast and Ufi Gel Hard was not affected by both disinfection methods evaluated ($P > 0.05$).
4. When the materials were not submitted to the disinfection methods (control groups), no significant differences were found between the mean

linear dimensional change of the heat-polymerizing denture base acrylic resin Lucitone 550 and the autopolymerizing reline acrylic resins ($P > 0.05$).

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