Effect of Disinfection by Microwave Irradiation on the Strength of Intact and Relined Denture Bases and the Water Sorption and Solubility of Denture Base and Reline Materials

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ABSTRACT: This study evaluated the influence of microwave disinfection on the strength of intact and relined denture bases. Water sorption and solubility were also evaluated. A heat-polymerized acrylic resin (Lucitone 550) was used to construct 4-mm-thick (n = 40) and 2-mm-thick (n = 160) denture bases. Denture bases (2-mm) were relined with an autopolymerizing resin (Tokuso Rebase Fast, Ufi Gel Hard, Kooliner, or New Truliner). Specimens were divided into four groups (n = 10): without treatment, one or seven cycles of microwave disinfection (650 W for 6 min), and water storage at 37°C for 7 days. Specimens were vertically loaded (5 mm/min) until failure. Disc-shaped specimens (50 mm × 0.5 mm) were fabricated (n = 10) to evaluate water sorption and solubility. Data on maximum fracture load (N), deflection at fracture (mm), fracture energy (N mm), water sorption (%), and solubility (%) were analyzed by two-way analysis of variance and Student–Newman–Keuls tests ($\alpha = 0.05$). One cycle of microwave disinfection decreased the deflection at fracture and fracture energy of Tokuso Rebase Fast and New Truliner specimens. The strength of denture bases microwaved daily for 7 days was similar to the strength of those immersed in water for 7 days. Microwave disinfection increased the water sorption of all materials and affected the solubility of the reline materials. © 2007 Wiley Periodicals, Inc. J Appl Polym Sci 107: 300–308, 2008

Key words: crosslinking; dental polymers; fracture; resins; tension

INTRODUCTION

Although research is continuously striving to improve the mechanical properties of acrylic resins, denture fracture remains one of the most common problems encountered by patients and prosthodontists.[1–5] This problem may be attributed to the several factors that affect the strength of the denture bases. Strength is the maximal stress required to fracture a structure, and any factor that exacerbates the deformation of the base or alters its stress distribution may predispose the denture to fracture.[6] It is well known that after relining, the resistance to plastic deformation of a denture base is significantly decreased.[7,8] Studies have demonstrated that some autopolymerizing reline resins appeared to perform better overall in the clinical situation than others.[9,10] This might well be related to the fact that the physicomechanical properties of the reline materials vary considerably[7,11–14] According to Chai et al.,[15] the mechanical properties of relined denture base acrylic resin specimens is dependent on the bulk strength of the denture base and reline materials and on the ability of the reline material/denture base acrylic resins to bond to each other. Hence, knowledge of the mechanical properties of relined denture base specimens is more clinically relevant than the data from the bulk reline material alone.[7] Currently, a number of studies have examined the effect of relining on the flexural strength of simple-shaped specimens;[7,8,15–17] however, no information is available concerning the effect of relining on the strength of denture base-shaped specimens.

Sterilization and disinfection have become popular and widely used methods for eradicating microorganisms from the surface of denture base acrylic resins[18] and controlling cross-contamination.[19,20] Among the disinfection protocols, microwave irradiation has proved to be an effective method for disinfection of dentures.[21,22] However, it is desirable that the physicomechanical properties of denture bases remain unaltered after microwave disinfection.

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Previous studies have shown contradictory findings. It has been reported that microwave irradiation did not result in significant changes in the hardness[23] and flexural strength[24] of denture base acrylic resins. On the other hand, some researchers observed that microwave disinfection at 650 W for 6 min decreased significantly the flexural strength of two autopolymerizing reline resins[13] and the surface hardness of five brands of acrylic resin denture teeth.[25] In those studies, all specimens were immersed in 200 mL of distilled water while subjected to microwave disinfection. The decrease in mechanical strength may be attributed to the heating generated during microwave disinfection,[26] which may have increased the water absorption into the materials, thus decreasing the properties because of a plasticizing effect of the absorbed water molecules.[7,27,28] However, this hypothesis has not been verified experimentally. Moreover, it is important to consider that only simply shaped specimens were evaluated in all cited studies. No information was identified regarding the effect of microwave disinfection on the physicomechanical properties of denture-shaped specimens.

Thus, the aim of this study was to evaluate the effect of microwave disinfection on the strength of intact and relined denture bases and on the water sorption and solubility of the materials involved. The null hypothesis tested was that microwave disinfection would not affect the strength of denture bases or the water sorption and solubility of the materials.

EXPERIMENTAL

Table I summarizes the four autopolymerizing reline resins and one heat-polymerized acrylic resin used in this study. Tokuso Rebase Fast and Ufi Gel Hard are materials that contain high percentages of a crosslinking agent, whereas New Truliner and Kooliner contain a monofunctional methacrylate monomer, isobutyl methacrylate, as the principal ingredient of the liquid without a crosslinking agent. The Lucitone 550 material was selected as representative of the poly(methyl methacrylate) heat-polymerized acrylic resins that are commonly used for the fabrication of denture bases.

A standard brass cast simulating a maxillary edentulous arch with no undercuts was used to construct intact and relined denture bases. To fabricate the intact denture bases, a denture base pattern was waxed on the standard brass cast with a 4.0-mm record base wax (Wilson, Polidental Indústria e Comércio, Ltda., São Paulo, Brazil), and a standard silicone mold (RTV 1312, Daltomare Indústria e Comércio, Ltda., Santo Amaro, São Paulo, Brazil) was made. This mold was used to construct 4-mm

TABLE I
Materials Used in This Study

Product	Manufacturer	Type	Powder/liquid ratio	Polymerization condition	Composition		Batch number	
					Powder	Liquid	Powder	Liquid
New Truliner	Harry Bosworth Co. (Skokie, IL)	Autopolymerizing acrylic resin	8.04 g/6 mL	12 min at room temperature	PEMA	IBMA, DBP	0212-703	0304-194-X
Kooliner	GC America, Inc. (Alsip, IL)	Autopolymerizing acrylic resin	8.4 g/6 mL	10 min at room temperature	PEMA	IBMA	0208282	0206251
Ufi Gel Hard	Voco (Cuxhaven, Germany)	Autopolymerizing acrylic resin	8.8 g/5 mL	7 min at room temperature	PEMA	1,6-HDMA	330936	321892
Tokuso Rebase Fast	Tokuyama Co., Ltd. (Tokyo, Japan)	Autopolymerizing acrylic resin	8.224 g/4 mL	5.5 min at room temperature	PEMA	MAOP, 1,6-HDMA	4641	17681
Lucitone 550	Dentsply Indústria e Comércio, Ltda. (Rio de Janeiro, Brazil)	Heat-polymerized acrylic resin	21 g/10 mL	90 min at 73 and 100°C for 30 min	PMMA	MMA, EDGMA	68300	37375

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

complete denture record bases by the placement of melted wax into the denture base area of the mold and then repositioning of the standard brass cast into the mold and wax combination. Lateral holes in the mold provided vents for the excess melted wax.

The standard brass cast with the record base wax was flasked in type III dental stone (Vigodent S.A. Indústria e Comércio, Bonsucesso, Rio de Janeiro, Brazil) according to the conventional flasking procedure.[29] After 1 h, the flask (Bethil Indústria e Comércio, Ltda., Marília, São Paulo, Brazil) was immersed in running boiling water to soften the wax pattern. The flask was separated, the wax was eliminated, and the standard brass cast was thoroughly cleaned with boiling water and liquid soap (Limpol, Bombril-Cirio, São Paulo, Brazil). Two coats of sodium alginate (Cel-Lac, SSWhite, Rio de Janeiro, Brazil) were used as a mold separator. The heat-polymerized acrylic resin Lucitone 550 was prepared according to the manufacturer's instructions (Table I). After the mold was filled fully with the dough resin, a polyethylene film was placed between the stone surfaces and the dough to allow trial closure under compression (500 kgf) in a hydraulic press (Delta Máquinas Especiais, Vinhedo, São Paulo, Brazil) for 5 min. The flasks were opened, and the excess material was removed with a carver (Faber Castell S.A., São Carlos, Brazil). The final closure was made with a load of 1250 kgf for 25 min. The flasks were then clamped tight and placed in a thermostatically controlled water bath (Termotron P-100, Termotron Equipamentos, Piracicaba, Brazil), and the denture base acrylic resin was polymerized according to the manufacturer's recommendations (Table I). After polymerization, each flask was bench-cooled at room temperature for 30 min and for 15 min under running water before the denture bases were removed from the flask. Excess flash was removed with a tungsten carbide bur (Edenta AG, AG/UG, St. Gallen, Switzerland), and the intact denture bases were stored in distilled water at 37°C for 50 ± 2 h before testing.[30]

The same standard brass cast used to construct intact denture bases was 2-mm-spaced with record base wax. This waxed standard cast was used to prepare a second standard RTV 1312 silicone mold, which was used to produce 160 similar master casts 2 mm larger than the unspaced standard brass cast.

To obtain the 2-mm-thick complete denture record bases, each cast was placed into the RTV silicone mold used to construct the intact denture bases. The space between the type IV dental stone casts and the RTV silicone mold was filled with melting wax. After cooling, the 2-mm-thick record bases were retrieved and flasked with artificial stone. The procedures followed were exactly the same as those described in the early part of the experiment, and the denture bases were processed. These denture bases were stored in distilled water at 37 ± 1°C for 50 ± 2 h before relining.[30]

For the relining procedure, the 2-mm-thick denture bases were placed back into the standard cast, sealed with wax, and flasked. After the stone had set, the flasks were opened and immersed in running boiling water to remove the wax around the denture bases. The tissue surface of the denture base was cleaned, dried, and treated according to the manufacturer's instructions for each reline material. The Tokuso Rebase Fast (Rebase Aid), New Truliner (Bosworth bonding liquid), and Ufi Gel Hard (Ufi Gel Hard conditioner) bonding agents were applied carefully with a brush inside the denture base tissue surfaces and allowed to dry before the introduction of the resin. Because of the absence of a bonding agent in the Kooliner material, the monomer liquid of Lucitone 550 was used as a substitute. This procedure was based on the results of a previous study,[31] which demonstrated that wetting the denture base resin surface with Lucitone 550 monomer improved the sites for bonding and promoted the highest flexural bond strength for the material Kooliner. The autopolymerizing reline resins were proportioned and mixed according to the manufacturers' specifications and were poured into the reline area. The flask was closed and left in the hydraulic press (500 kgf) until polymerization was complete. After hardening, the excess material was removed with a tungsten carbide bur. The total thickness of the relined maxillary simulated denture bases was 4-mm.

The intact and relined specimens of each resin were divided into four groups to provide a sample size of 10. The test groups are described in Table II.

The nontissue side of the denture bases was placed on the table of a universal testing machine (MTS 810, MTS Systems Corp., Eden Prairie, MN)

TABLE II
Test Groups for Fracture Tests

Group	Description
Control group 1	Specimens were tested without being disinfected.
Test group 1	Specimens were tested after being immersed in 200 mL of water and disinfected (650 W for 6 min) individually.
Control group 2	Specimens were tested after being immersed in distilled water at 37°C for 7 days.
Test group 2	Specimens were tested after being immersed in 200 mL of water and microwaved (650 W for 6 min) daily for 7 days, being stored in water at 37°C between exposures. This group was intended to detect any possible cumulative effect of microwave disinfection.

Figure 1 Fracture test.

and loaded in compression at 5 mm/min by a 5-mm-diameter rounded rod mounted in the upper jaws of the test machine (Fig. 1). The load was applied to the tissue side of the base at an area corresponding to the premolar and first molar regions until failure.[2,32,33] The mean and standard deviation of the maximum fracture load (N), deflection at fracture (mm), and fracture energy (N mm) were calculated.

Water sorption/solubility testing

Water sorption

A stainless steel split mold (50 mm in diameter and 0.5 mm thick) was used to prepare the specimens (discs) in accordance with American Dental Association (ADA) specification number 17.[34] All materials were mixed and manipulated according to the manufacturers' instructions. The specimens of each resin were processed with the curing cycles listed in Table I. After processing, all specimens were dried in an oven (Olidef CZ, Ribeirão Preto, São Paulo, Brazil) at 37 ± 1°C for 24 h with a desiccant (silica gel) and then removed to a similar desiccator at room temperature for 1 h. Each specimen was weighed, and the previously described cycle was repeated until the loss in mass of each specimen disc was not more than 0.5 mg in any 24-h period. After the specimens of each material reached a constant mass, they were divided into four experimental groups (Table III). During the weighings, the specimens were removed from the water with tweezers, wiped with a clean, dry hand towel until free from visible moisture, waved in the air for 15 s, and weighed 1 min after removal from the water. The value for water sorption was calculated for each disc in terms of the percentage of mass gained over the desiccated mass. The percentage of water sorption was determined with the following formula:

$$\text{Sorption } (\%) = (W_2 - W_1)/W_1 \times 100$$

where W_1 is the initial weight of the specimen after drying and W_2 is the weight of the specimen after treatment.

Solubility

After the final weighing for sorption determinations, specimens (discs) of control group 2, test group 1, and test group 2 were reconditioned to a dry constant weight according to procedures described previously. Specimens of control group 1 were not tested for solubility because they were immersed in water for only 6 min. The value for solubility was calculated for each disc in terms of the percentage of mass lost in relation to the initial desiccated weight. The percentage of solubility was determined with the following formula:

$$\text{Solubility } (\%) = (W_1 - W_3)/W_3 \times 100$$

where W_1 is the initial desiccated weight and W_3 is the final weight of the specimen after ultimate drying.

Two-way analysis of variance tests were conducted to determine the effects of the material and treatments on the strength, water sorption, solubility, and interactions between the two factors. Student–Newman–Keuls post hoc test was used to determine differences between mean values ($\alpha = 0.05$).

TABLE III
Water Sorption Test Groups

Group	Group description
Control group 1	Specimens were weighed after being immersed in distilled water at 37°C for 6 min.
Test group 1	Specimens were immersed in 200 mL of water and submitted to a single microwave disinfection cycle (650 W for 6 min) and then weighed after being immersed in distilled water at 37°C for 7 days.
Control group 2	Specimens were weighed after being immersed in distilled water at 37°C for 7 days.
Test group 2	Specimens were immersed in 200 mL of water and microwaved (650 W for 6 min) daily for 7 days, being stored in water at 37°C between exposures. Hence, the specimens were weighed after being immersed in distilled water at 37°C for 7 days. This group was intended to detect any possible cumulative effect of microwave disinfection.

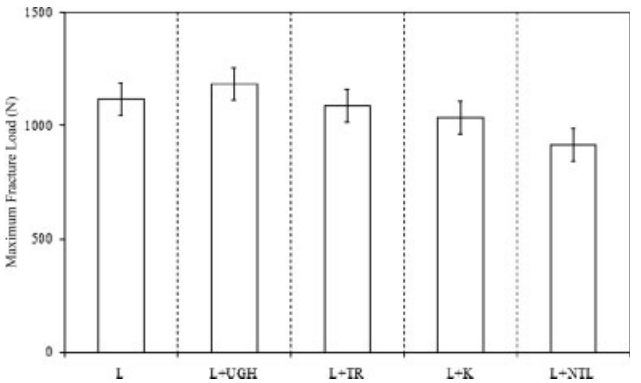

Figure 2 Maximum fracture load of intact and relined denture bases. Vertical bars indicate 95% confidence intervals (L = Lucitone 550; UGH = Ufi Gel Hard; TR = Tokuso Rebase Fast; K = Kooliner; NTL = New Truliner).

RESULTS

The results of the maximum fracture load, deflection at fracture, and fracture energy values are illustrated in Figures 2–4, respectively. Maximum fracture load values were analyzed by a two-way analysis of variance, which showed a significant effect of materials ($P < 0.001$) but no significant effect ($P = 0.345$) of treatment (Table III). Figure 2 shows that the maximum fracture load values of intact denture bases were significantly higher than those of denture bases relined with New Truliner. This study failed to detect any significant differences in maximum fracture load between the intact denture bases and those relined with Tokuso Rebase Fast, Ufi Gel Hard, and Kooliner. Denture bases relined with New Truliner produced the lowest mean maximum fracture load values.

The two-way analysis of variance for the deflection at fracture values (Table III) showed significant differences for the two main factors (material, $P < 0.001$, and treatment, $P < 0.001$) and their interaction ($P < 0.001$). Figure 3 shows that one cycle of microwave disinfection promoted a significant decrease in deflection at fracture values of denture bases relined with New Truliner and Tokuso Rebase Fast. For all intact and relined denture bases, no significant differences were observed between seven cycles of microwave disinfection and water storage for 7 days. The deflection at fracture values of the intact denture bases and those relined with Kooliner and Ufi Gel Hard were not affected by either microwave disinfection (one and seven cycles) or water storage for 7 days.

When the specimens of control group 1 were compared, denture bases relined with New Truliner and Tokuso Rebase Fast showed higher deflection at fracture values than intact denture bases and those relined with Kooliner and Ufi Gel Hard, which were not significantly different from each other. No significant difference was observed between denture bases relined with New Truliner and Tokuso Rebase Fast. After microwave disinfection or water storage for 7 days, no significant differences were observed among denture bases, regardless of the reline material used.

For fracture energy values of denture bases, a two-way analysis of variance also revealed that there was a significant main effect of both the material ($P = 0.023$) and treatment ($P < 0.001$) as well as a significant interaction between these two factors ($P < 0.001$). The results of fracture energy followed the same pattern as those seen for deflection at fracture values (Fig. 4).

The water sorption results of the materials are given in Tables IV and V. From Table IV, it can be seen that all reline materials specimens showed increased water sorption ($P < 0.05$) after being sub-

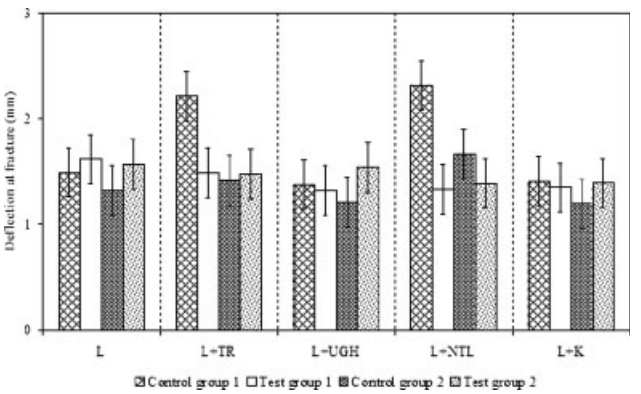

Figure 3 Deflection at fracture of intact and relined denture bases. Vertical bars indicate 95% confidence intervals (L = Lucitone 550; UGH = Ufi Gel Hard; TR = Tokuso Rebase Fast; K = Kooliner; NTL = New Truliner).

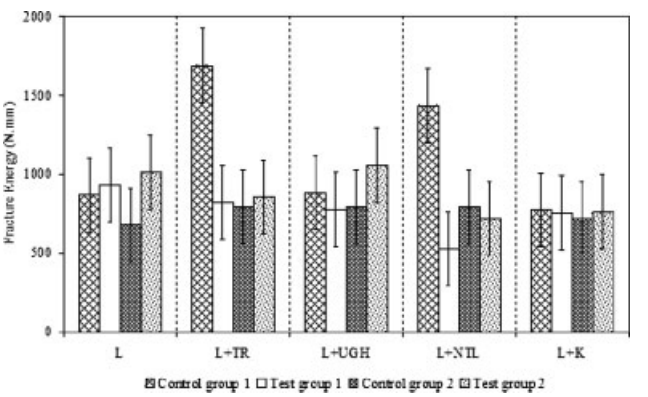

Figure 4 Fracture energy of intact and relined denture bases. Vertical bars indicate 95% confidence intervals (L = Lucitone 550; UGH = Ufi Gel Hard; TR = Tokuso Rebase Fast; K = Kooliner; NTL = New Truliner).

TABLE IV
Water Sorption Means (%) of the Material × Treatment Interaction (Control Group 1 × Test Group 1)

	Control group 1	Test group 1
New Truliner	0.0959 A^a (0.0235)	0.4292 AB^b (0.0363)
Kooliner	0.0872 A^a (0.0011)	0.5375 A^b (0.0802)
Ufi Gel Hard	0.0788 A^a (0.0243)	0.4579 AB^b (0.0837)
Tokuso Rebase Fast	0.0774 A^a (0.0353)	0.6426 A^b (0.1163)
Lucitone 550	0.0882 A^a (0.0301)	0.2886 B^a (0.0301)

Standard deviations are given in parentheses. Vertically, means designated with the same capital letters were not statistically different ($P > 0.05$). Horizontally, means designated with the same superscript were not statistically different ($P > 0.05$).

mitted to a single microwave disinfection cycle. The specimens of the denture base resin Lucitone 550 showed no significant change after one cycle of microwave irradiation ($P > 0.05$). Within control group 1 and test group 1, no significant differences ($P > 0.05$) in water sorption were found among the reline materials. After a single microwave irradiation, Kooliner and Tokuso Rebase Fast produced higher water sorption than Lucitone 550 specimens ($P < 0.05$).

Table V shows that materials Kooliner, Tokuso Rebase Fast, and Lucitone showed significant increases in water sorption after being microwaved daily for 7 days. The opposite behavior was observed for New Truliner. After 7 days of water storage, New Truliner produced the highest water sorption mean value ($P < 0.05$) among the reline materials. After being microwaved daily for 7 days, Tokuso Rebase Fast produced the highest water sorption mean value ($P < 0.05$) among the autopolymerizing reline resins. In both control group 2 and test group 2, the water sorption of the denture base resin Lucitone 550 was higher than that of the reline resins.

The results from solubility measurements are presented in Table VI. One cycle of microwave disinfection decreased the solubility of New Truliner and Ufi Gel Hard ($P < 0.05$). No significant change in solubility was found for Kooliner and Tokuso Rebase Fast reline materials after one cycle of microwave disinfection, whereas the solubility of materials New Truliner, Tokuso Rebase Fast, and Kooliner was increased after the specimens were microwaved daily for 7 days. Daily microwave disinfection decreased the solubility of Ufi Gel Hard specimens ($P < 0.05$). The solubility of the denture base resin Lucitone 550 was not affected by microwave disinfection.

Within control group 2, New Truliner, Ufi Gel Hard, and Kooliner showed higher solubility than Tokuso Rebase Fast and Lucitone 550. After a single microwave irradiation, New Truliner, Kooliner, and Tokuso Rebase Fast produced the highest solubility mean values ($P < 0.05$), followed by Ufi Gel Hard and Lucitone 550. After being microwaved daily for 7 days, New Truliner and Kooliner produced the highest solubility mean values ($P < 0.05$), followed by Ufi Gel Hard and Tokuso Rebase Fast. Lucitone 550 produced the lowest solubility mean value ($P < 0.05$).

DISCUSSION

In this study, the mechanical behavior of the intact and relined denture bases, before and after microwave disinfection, was evaluated by means of flexural properties such as the maximum fracture load (N), deflection at fracture (mm), and fracture energy (N mm). The null hypothesis that relining and microwave disinfection would not affect the strength of denture bases was rejected.

The results of this study did not reveal any significant effect of microwave disinfection on the maximum fracture load values of denture bases. However, the maximum fracture load values of the denture bases varied according to the reline material used. The denture bases relined with Tokuso Rebase Fast, Ufi Gel Hard, and Kooliner produced maximum fracture load values higher than those relined with New Truliner. These results may be attributed to the differences in the chemical composition of the reline materials[11] and the ability of the denture base acrylic resin to bond to reline material.[35] Previous studies have demonstrated that flexural strength values of relined specimens were lower than those of intact specimens and the magnitude of this effect was small when the strongest bulk reline materials were used.[7,16,36] In this investigation, no significant differences in maximum fracture load were found between the intact denture bases and those relined with Tokuso Rebase Fast, Ufi Gel Hard, and Kooliner.

TABLE V
Water Sorption Means (%) of the Material × Treatment Interaction (Control Group 2 × Test Group 2)

	Control group 2	Test group 2
New Truliner	1.1995 A^a (0.0224)	0.9740 A^b (0.0327)
Kooliner	0.8619 B^a (0.0271)	1.0080 AB^b (0.0035)
Ufi Gel Hard	0.8830 B^a (0.0249)	1.0760 B^a (0.0224)
Tokuso Rebase Fast	0.9233 B^a (0.0269)	1.1829 C^b (0.0168)
Lucitone 550	1.6172 C^a (0.0126)	2.1946 D^b (0.0394)

Standard deviations are given in parentheses. Vertically, means designated with the same capital letters were not statistically different ($P > 0.05$). Horizontally, means designated with the same superscript were not statistically different ($P > 0.05$).

TABLE VI
Solubility Means (%) of the Material × Treatment Interaction

	7 days of water immersion	One cycle of microwave disinfection	Daily microwave disinfection (7 days)
New Truliner	0.2507 A^a (0.0349)	0.1790 A^b (0.0203)	0.3238 A^c (0.0136)
Kooliner	0.1685 B^a (0.0005)	0.2060 A^a (0.0054)	0.3286 A^b (0.0167)
Ufi Gel Hard	0.2252 AB^a (0.0146)	0.0685 B^b (0.0202)	0.1251 B^b (0.0014)
Tokuso Rebase Fast	0.0913 C^a (0.0056)	0.1389 A^{ab} (0.0192)	0.1920 B^b (0.0312)
Lucitone 550	0.0644 C^a (0.0030)	0.0265 B^a (0.0046)	0.0021 C^a (0.0030)

Standard deviations are given in parentheses. Vertically, means designated with the same capital letters were not statistically different ($P > 0.05$). Horizontally, means designated with the same superscript were not statistically different ($P > 0.05$).

The liquids of Tokuso Rebase Fast and Ufi Gel Hard contain high percentages of crosslinking agent 1,6-hexanediol dimethacrylate,[37] which is responsible for their high flexural strength values in comparison with noncrosslinked reline resins.[11,14] Considering these features, we can suppose that the maximum fracture load values observed in denture bases relined with Tokuso Rebase Fast and Ufi Gel Hard may be attributed to the high bulk strength of these reline materials.

The denture bases relined with Kooliner had a maximum fracture load mean value similar to those of the intact ones and those relined with Tokuso Rebase Fast and Ufi Gel Hard. These results were unexpected because, in an earlier study,[14] Kooliner material produced specimens with lower flexural strength values than Tokuso Rebase Fast and Ufi Gel Hard materials. Accordingly, the results from Arima et al.[11] demonstrated that Kooliner exhibited lower modulus of elasticity and bulk flexural strength than Tokuso Rebase Fast. However, these studies evaluated the resistance to deformation or fracture of the bulk of the reline material under a flexural load. These differences suggest that the maximum fracture load of denture bases can be influenced by other factors than those related to the bulk strength of the autopolymerizing denture reline polymer. One of these factors is the ability of a relining material to bond to the denture base acrylic resin. A denture base surface treatment before relining is necessary to promote adhesion between the reline material and the denture base acrylic resin. The material Kooliner does not have a related primer, and its manufacturer recommends the roughening of the surfaces to be bonded as the only surface treatment before relining. To achieve optimal bonding results for Kooliner, wetting the bond surfaces with methyl methacrylate for 180 s was used in this study, as suggested by Leles et al.,[31] who observed that this surface treatment provided an increase in bond strength between Kooliner and Lucitone 550. Therefore, the improved bond strength of the reline material Kooliner to the denture base acrylic resin Lucitone 550 may have played an important role in the maximum fracture load values of denture bases relined with Kooliner.

It is interesting to note that despite the similar compositions of the noncrosslinked reline resins Kooliner and New Truliner (Table I), denture bases relined with New Truliner showed lower maximum fracture load values than those relined with Kooliner. In addition, the denture bases relined with New Truliner demonstrated higher deflection at fracture and fracture energy values than intact denture bases and those relined with Kooliner and Ufi Gel Hard. Moreover, although most of the intact and relined denture bases showed a single fracture along the midline of specimens, New Truliner denture bases demonstrated partial fracture. For these specimens, fracture was initiated at the posterior border, and the crack propagated toward the point of load application. This may be related to the plasticizer di-*n*-butyl phthalate contained in the liquid of the material New Truliner that affects the flexibility of polymeric chains.[11] Another fact that may have influenced these results is the manufacturer's liquid/powder (1 mL/1.34 g) ratio recommendation for the material New Truliner, which is higher than that of the other reline materials tested. This would lead to increased residual monomer content,[37,38] which may act as a plasticizer, thereby reducing interchain forces so that deformation occurs more easily under load.[39,40] These results together with those of previous *in vitro* studies[11,13,36] suggest that the material New Truliner should be used as a short-term reline material because of its limited mechanical properties. Material Tokuso Rebase Fast also showed higher deflection at fracture and fracture energy mean values than Kooliner and Ufi Gel Hard. This may be attributed to the presence of β-methacryloyl oxyethyl propionate,[16,17] a monofunctional monomer with two ester bonds that forms long flexible polymer chains,[11] in the liquid of Tokuso Rebase Fast. The higher deflection at fracture values promoted by Tokuso Rebase Fast and New Truliner may suggest a higher propensity to deformation of the relined denture bases. Further clinical investigation to establish and characterize the relevance of these results is warranted. Consider-

ing that the plastic deformation of an acrylic resin beyond its proportional limit permanently alters the dimension of the denture base,[7] we think that it is desirable that denture bases show moderate flexibility.

Interestingly, the deflection at fracture and fracture energy values of the denture bases relined with Tokuso Rebase Fast and New Tuliner decreased after one cycle of microwave disinfection. These findings could be attributed in part to further polymerization reaction.[41–44] To different extents, residual monomers may affect the strength of the polymers because these molecules facilitate the movement of polymer chains to various degrees.[28] The reduction in residual monomer content in reline resins promoted by microwave irradiation has been recently demonstrated.[43,44] Probably, the high temperature of the water enhanced the diffusion of remaining residual monomer molecules[45,46] to the active sites of the polymer chains,[41] thus resulting in further polymerization. Simultaneously, one cycle of microwave disinfection enhanced the uptake of water by the specimens, regardless of the materials. The plasticizing effect of absorbed water on the mechanical properties of polymers is well known.[8,11,17] However, the results from this investigation revealed that microwaved denture bases relined with Tokuso Rebase Fast and New Truliner showed decreased deflection and absorbed less energy until fracture, thus suggesting that one cycle of microwave irradiation promoted more rigid specimens. It could be assumed that the process of further polymerization overcame any detrimental effects caused by absorbed water molecules. Even though daily microwave disinfection for 7 days increased the water sorption of some materials, no changes in strength were observed. These results might be related to the fact that the highest rate of water sorption takes place within 24 h.[47]

It was apparent that the solubility of materials New Truliner and Ufi Gel Hard decreased after one cycle of microwave disinfection, whereas the other materials showed no change. The solubility of the acrylic resins represents the amount of water-soluble ingredients, unreacted monomers, plasticizers, and initiators that leached out during the 7 days the specimen was immersed in water. Although this needs further experimental verification, the heating generated during microwave irradiation probably provided additional polymerization, thus promoting a higher degree of conversion of the resin matrix.[44] Increased density of the polymer system may have led to limited mobility of residual components and consequently to lower solubility.[11] On the other hand, the solubility of materials New Truliner and Kooliner was further increased after daily microwave disinfection for 7 days. As opposed to the other materials, these reline resins contain no cross-linking agent. It has been demonstrated that cross-linking agents play an important role in the reduction of solubility of reline resins.[11,12]

Despite the changes in water sorption and solubility after seven cycles of microwave disinfection or 7 days of water storage, all denture bases demonstrated similar deflection at fracture and fracture energy. These findings could be attributed to the leaching of the residual monomer from the specimens[46,48,49] and a continuous polymerization reaction[28,50] during immersion in water.

The interpretation of the results of this investigation must be made with caution because the study design used is limited in predicting the strength of denture bases in clinical use. Thermocycling and cyclic loading are recommended in further studies to better simulate intraoral conditions. Further studies should be undertaken to detect the effect of microwave disinfection on the degree of conversion of denture base materials.

CONCLUSIONS

Under the limitations of this study, the following conclusions can be drawn:

1. The maximum fracture load of intact and relined denture bases remained unaffected after one and seven cycles of microwave disinfection, regardless of the reline material used.
2. Denture bases relined with Tokuso Rebase Fast, Ufi Gel Hard, and Kooliner produced maximum fracture load similar to that of the intact denture bases. Denture bases relined with New Truliner produced the lowest maximum fracture load mean value.
3. One cycle of microwave disinfection significantly decreased the deflection at fracture and fracture energy values of denture bases relined with Tokuso Rebase Fast and New Truliner.
4. Within control group 1, the highest deflection at fracture and fracture energy values were observed in denture bases relined with New Truliner and Tokuso Rebase Fast.
5. After microwave disinfection (one and seven cycles) or 7 days of water storage, there were no significant differences in deflection at fracture and fracture energy values between intact and relined denture bases, regardless of the reline material used.
6. Microwave disinfection increased the water sorption percentage of all materials and affected the solubility of the reline resins.

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