Effect of repeated microwave disinfection on surface roughness and baseplate adaptation of denture resins polymerized by different techniques

Efeito da desinfecção repetida por microondas sobre rugosidade superficial e adaptação de bases de resinas polimerizadas por diferentes técnicas

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Abstract

Purpose: To evaluate the cumulative effect of two protocols of microwave disinfection (Protocol 1: 690 W/6 min; Protocol 2: 345 W/6 min) on surface roughness (Ra) and baseplate adaptation of two denture resins polymerized by microwave energy (Onda Cryl) or hot water bath (QC-20).

Methods: For Ra evaluation, rectangular specimens were fabricated and subjected to the following disinfection treatment (n=8/group): 1) Control (no disinfection), 2) Protocol 1, and 3) Protocol 2. Ra was measured using a profilometer at baseline (T0) and after two disinfection procedures (T1, T2) with a 7-day interval immersed in distilled water. To evaluate dimensional stability, maxillary baseplates were divided into the disinfection treatment groups (n=6), and adaptation was measured by weighing a silicon film reproducing the gap between resin baseplate and a metallic master model.

Results: Ra had a significant interaction between type of resin/polymerization technique, disinfection treatment, and number of disinfection procedures ($P<0.001$). For Ra, Protocol 2 and control groups had similar increase of Ra over time, but Protocol 1 groups showed a significant decrease of Ra in T2. Baseplate adaptation was affected by a significant interaction between disinfection treatment and number of disinfection procedures ($P<0.001$), and Protocol 1 yielded the largest mean in T2.

Conclusion: Onda Cryl displayed greater changes of Ra and adaptation than QC-20. Protocol 1 promoted overall damage to both types of denture resins after two disinfection procedures.

Key words: Dental polymers; denture resins; microwave disinfection; surface roughness; dimensional stability

Resumo

Objetivo: Avaliar o efeito cumulativo de dois protocolos de desinfecção por energia de micro-ondas (Protocolo 1: 690 W/6 min; Protocolo 2: 345 W/6 min) na rugosidade superficial (Ra) e adaptação de bases de dentadura de duas resinas polimerizadas por micro-ondas (Onda Cryl) ou banho de água quente (QC-20).

Metodologia: Para Ra, espécimes retangulares foram fabricados e divididos de acordo com o tratamento de desinfecção (n=8/grupo): 1) Controle (sem desinfecção), 2) Protocolo 1, e 3) Protocolo 2. Para medir Ra usou-se um rugosímetro no baseline (T0) e após 2 procedimentos de desinfecção (T1, T2) com intervalo de 7 dias de imersão em água destilada. Para avaliar a estabilidade dimensional, bases maxilares foram divididas nos 3 grupos (n=6) e a adaptação foi medida por pesagem de uma película de silicone que reproduzia o espaço entre a base de resina e um modelo-mestre metálico.

Resultados: Para Ra, houve interação significativa entre tipo de resina e técnica de polimerização, tratamento de desinfecção, e número de procedimentos desinfecção ($P<0,001$). Os grupos Protocolo 2 e controle apresentaram aumento semelhante de Ra ao longo do tempo, mas os grupos Protocolo 1 tiveram uma redução significativa de Ra em T2. A adaptação da base foi afetada por uma interação significante entre tratamento de desinfecção e número de procedimentos de desinfecção ($P<0,001$); o Protocolo 1 apresentou a maior média em T2.

Conclusão: Onda Cryl teve maiores alterações de Ra e adaptação que QC-20. O Protocolo 1 promoveu dano geral para ambos os tipos de resina após dois procedimentos de desinfecção.

Palavras-chave: Polímeros; resinas acrílicas; desinfecção por micro-ondas; rugosidade superficial; estabilidade dimensional

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Received: October 11, 2008
Accepted: December 2, 2008

Introduction

Denture bases for conventional or implant-supported prostheses usually are made of methacrylate-based polymers activated by thermal energy delivered by different methods, *e.g.*, immersion in hot water bath, microwave irradiation, and injection-molding technique. These processing methods can affect resin physical properties mainly related to the degree of monomer conversion and porosity (1-3), which in turn may impact surface characteristics and prosthesis survival. Additionally, during clinical service, mechanical and chemical stresses by oral function, diet, habits, and hygiene procedures over time may cause increasing material degradation with alteration of surface color and texture, distortion, wear, and fracture.

Disinfection of contaminated dentures is necessary to reduce or eliminate pathogens in cases of stomatitis related to continuous denture use. An ideal denture disinfection procedure should be efficient, economic, fast, and easy to perform to provide good adherence among patients and caregivers, especially in places with large demand of care, such as oral medicine clinics, hospitals, and nursing homes. Microwave disinfection has been used as an alternative method to soaking in chemical solutions because is lethal to several microorganisms, does not induce resistance of *Candida albicans*, does not alter denture color or smell, does not have expiration date, and is not allergenic (4-9).

Different time and power settings of microwave irradiation have been proposed for denture disinfection, but their side-effects on material properties still are unclear. High wattage and long irradiation time seem to yield significant denture distortion (5,10) and alteration of surface roughness (11), but resin hardness is not affected (12). Also, a previous study found that repeated microwave disinfection at 690 W for 6min promoted significant increase of baseplate distortion in a denture resin polymerized by microwave energy but not when the same resin was polymerized by conventional hot water bath (13). These results suggest that dimensional stability and other properties of denture base resins subjected to microwave disinfection may be influenced by a combined effect of type of resin/polymerization technique and microwave irradiation setting. Also, it is possible that repeated microwave disinfection promotes an additive effect with different gradient depending on the other factors.

Therefore, this study evaluated the cumulative effect of two irradiation power/time settings of microwave energy on surface roughness and baseplate adaptation of two types of denture resins polymerized by either microwave energy or hot water bath. The null hypothesis was that the outcome measures do not vary as a function of type of resin/polymerization technique, microwave irradiation setting, and number of microwave disinfection procedures.

Methodology

Two thermo-cured methacrylate-based resins for denture base were used. Brand name, manufacturer, composition, powder/liquid ratio, and polymerization technique of the tested materials are displayed in Table 1.

Surface roughness assessment

Thirty-six specimens (10×10×2 mm) were prepared for each resin according to the manufacturers' recommendations and packed into prepared molds in polycarbonate (for OndaCryl resin) or metallic (for QC-20 resin) flasks using a trial-technique with a wet cellophane film. Final packing was accomplished under 4.61 MPa (47 kgf/cm^2) pressure for 30 min. Polymerization methods are summarized in Table 1. After deflasking, resin flash was removed with a finishing bur in low speed. The test surface was ground with 600-, 1200-, 1500-, 2000-, and 2500- grit silicon carbide paper in a polishing machine (model DPU-10, Struers/Panambra Industrial e Técnica SA, São Paulo, SP, Brazil) under running water for 10 s. For each resin, the specimens were randomly divided into three subgroups to receive the experimental disinfection treatment:

1) No disinfection (control),
2) Protocol 1: immersion in 500 mL of distilled water and microwave irradiation at 690 W for 6 min (adapted from Neppelenbroek et al.) (14), or
3) Protocol 2: immersion in 500 mL of distilled water and microwave irradiation at 345 W for 6 min (adapted from Webb et al.) (6).

Table 1. Specifications of the two denture base resins tested in this study: commercial brand, manufacturer, principle chemical composition, powder/liquid ratio, and polymerization method.

Denture base resin/ Manufacturer	Chemical composition	Powder/Liquid ratio	Polymerization technique
OndaCryl/Artigos Odontológicos Clássico, São Paulo, Brazil	Powder: methyl methacrylate co-polymer, ethacrylate, dibutyl paleoteodine, benzoyl peroxide Liquid: methyl methacrylate, topanol, ethylene glycol dimethacrylate	21 mg/7 mL	Microwave energy using a domestic oven (LG Electronics, Model MS-115 ML, São Paulo, Brazil; output 1150 W, 2D turntable): 3 min at 345 W, 4 min at 0 W, and 3 min at 690 W. Bench cooling to room temperature.
QC-20/Dentsply Int. Inc., Chicago, IL, USA	Powder: methyl methacrylate co-polymer, ethacrylate, benzoyl peroxide Liquid: methyl methacrylate, hydroquinone, N,N-dimethyl-p-toluidine, ethylene glycol dimethacrylate	23 mg/10 mL	Hot water bath using a curing tank (Termotron P-100, Termotron Equipamentos, Piracicaba, Brazil): 20 min in boiling water at 100°C. Bench cooling to room temperature.

Curing was performed using a domestic microwave oven (LG Electronics, Model MS-115 ML, São Paulo, Brazil; output 1150 W, with 2D rotating plate). All groups were stored in water at 37°C between the baseline (T0) and the disinfection procedures (T1 and T2) with a 7-day interval. Average surface roughness (Ra) was measured using the surface analyzer Surface Roughness Tester SJ-201 (Mitutoyo Corporation, Japan), with accuracy of 0.01 µm. Each specimen was measured in duplicate, and the Ra values were averaged. Ra was recorded after the polishing procedure (baseline – T0) and after each of the two disinfection procedures (T1 and T2).

Dimensional stability assessment (adaptation test)

Eighteen specimens simulating a maxillary denture baseplate were fabricated with each denture resin. A vinyl polysiloxane (Elite Doublé, Zhermack, Rovigo, Italy) impression was obtained from a metallic master cast of an edentulous maxilla and poured with type III dental stone. A denture baseplate with approximately 2 mm-thickness was waxed on each cast and invested into the flasks, generating a mold for the resin. The resin preparation, packing, and processing followed the same procedures as described for the surface roughness test. The bases were deflasked, trimmed, and randomly divided into three groups to receive the disinfection treatment.

Tridimensional stability was measured by the method of weighing a silicone film reproducing the gap between resin baseplate and metallic master cast (1,12). A standardized portion of flow type vinyl polysiloxane (3M ESPE Express, St. Paul, USA) was prepared according to the manufacturer's instructions and coated the baseplate internal surface. The baseplate was positioned over the metallic master cast under an axial load of 40 N for 4-5 min. The resulting vinyl polysiloxane film was trimmed at a standardized borderline mark of the master cast and weighed using a precision balance (Mettler Toledo, model AG204, Switzerland). Measurements were performed immediately after the base finishing (baseline – T0) and after each of the two weekly disinfection procedures (T1 and T2). All groups were stored in distilled water at 37°C between measurements.

Statistical analysis

Data of the outcome measures surface roughness Ra (in micrometers) and baseplate adaptation (in grams) followed a normal distribution and were analyzed using Analysis of Variance for repeated measures (within-subject factor: Procedure [T0, T1, T2]; between-subject factors: Resin [OndaCryl, QC-20] and Disinfection treatment [Control, Protocol 1, Protocol 2]). Pairwise comparison of means was performed with Bonferroni's test. All tests were two-tailed, and a significance level of 0.05 was set to identify significant differences between group means.

Results

Figure 1 displays the Ra changes as a function of type of resin and disinfection treatment over time. Surface roughness Ra had a significant interaction between type of resin/polymerization technique, disinfection treatment, and number of disinfection procedures ($P<0.001$). Overall, for both resins Protocol 2 and control groups had similar increase of surface roughness from T0 to T2, but Protocol 1 groups showed a significant decrease of Ra from T1 to T2. Regarding Protocol 2 and control groups, final Ra in T2 was higher for Onda Cryl than for QC-20.

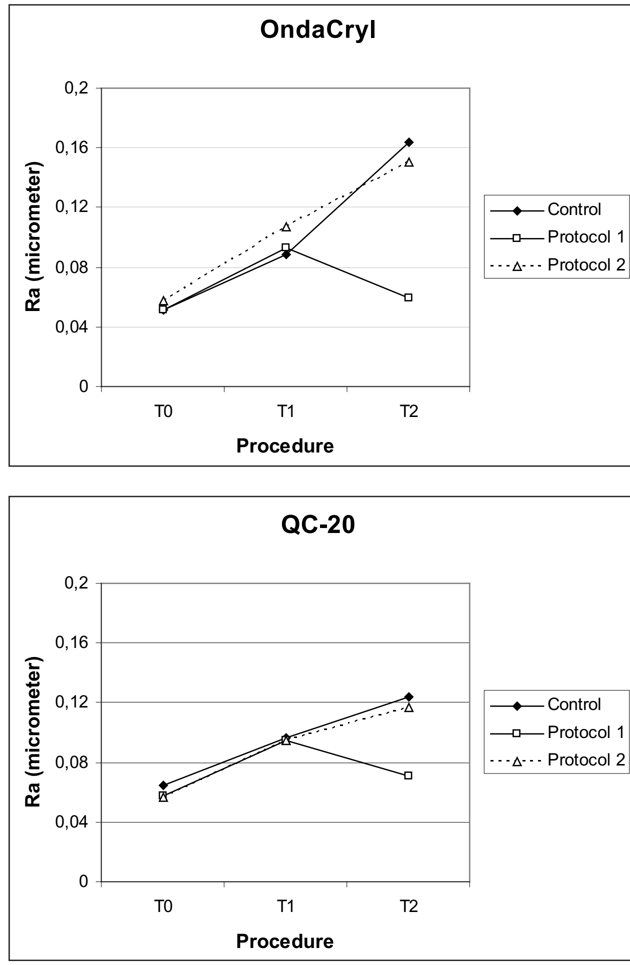
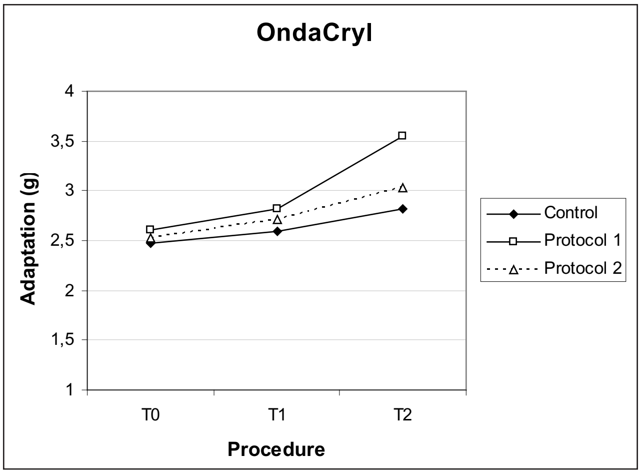


Fig.1. Ra mean values (in micrometers) of OndaCryl and QC-20 resins according to disinfection treatment groups and number of disinfection procedures. Control and Protocol 2 (345 W/6 min) groups showed similar behavior. A significant decrease of surface roughness ($P<0.05$) occurred after two microwave disinfection procedures with Protocol 1 (690 W/6 min).

Comparison of baseplate adaptation as a function of the independent variables is depicted in Figure 2. Coefficient of variation of the experimental groups varied from 5.2 % to 14.2 %. Adaptation was affected by a significant main effect of type of resin ($P<0.001$), and QC-20 (mean: 2.554 g; 95 % confidence interval: 2.487-2.622) showed lower mean values than Onda Cryl (mean: 2.803 g; 95 % confidence interval: 2.735-2.870). A significant interaction between disinfection treatment and number of disinfection procedures

(P<0.001) was found. Control and Protocol 2 groups were not statistically different, while Protocol 1 yielded the largest mean values in T2.



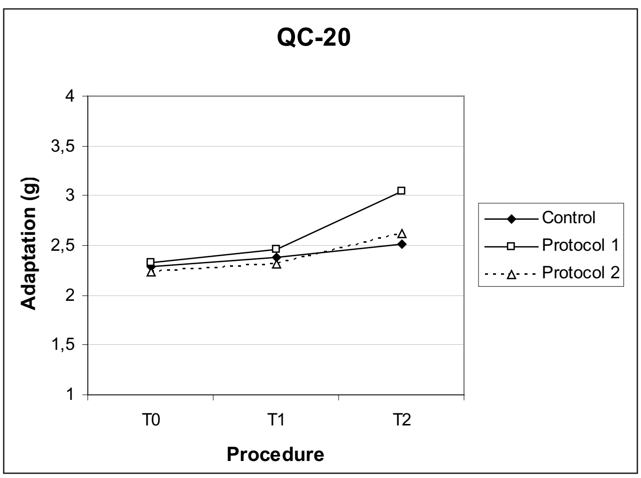


Fig.2. Baseplate adaptation mean values (in grams) of OndaCryl and QC-20 resins according to disinfection treatment groups and number of disinfection procedures. Control and Protocol 2 (345 W/6 min) groups showed similar behavior. Significant poorer adaptation (P<0.05) was measured after two microwave disinfection procedures with Protocol 1 (690 W/6 min).

Discussion

This study found that surface roughness and baseplate adaptation were affected by the combined effect of type of resin/polymerization technique, power/time setting of microwave irradiation, and number of disinfection procedures. Control and Protocol 2 (345 W/6 min) groups showed similar pattern independently from the number of disinfection procedures, while Protocol 1 (690 W/6 min) groups showed a significant decrease of surface roughness and poorer baseplate adaptation after two procedures of microwave irradiation.

Although overall pattern was similar for both types of resin, changes were slightly more pronounced for Onda Cryl. Thus, the combination of higher wattage and number of disinfection procedures seem to be more critical to affect the material polymerized by microwave energy. A previous study also found that repeated microwave disinfection at 690 W for 6 min promoted significant increase of baseplate distortion in one denture resin polymerized by microwave energy, but baseplate adaptation did not change when the same resin was processed using conventional hot water bath (13). Different methods used to polymerize the same denture resin seem to affect some physical-mechanical properties, such as dimensional stability, while other properties are not significantly altered. For example, it has been reported no deleterious effect on visible porosity for one conventional denture resin polymerized by microwave energy (15) nor significant differences in residual monomer levels for a conventional relining resin processed by microwaves (16). Another recent study on microwave disinfection of denture resins showed that intact specimens generally showed greater shrinkage after one or seven disinfection cycles than specimens relined with autopolymerizing resins (17). These findings suggest that a comprehensive evaluation of different material properties is necessary before a conclusive indication of polymerization method or disinfection procedure can be done. Furthermore, it is necessary to evaluate if the material alterations measured in laboratory experiments significantly affect clinical performance over time.

For surface roughness and baseplate adaption, Protocol 2 (345 W/6 min) proved to be safer than Protocol 1 (690 W/6 min) for both Onda Cryl and QC-20 resins in the tested conditions. In a previous study using the same method to measure dimensional stability of denture baseplates, Fleck et al. (13) also showed that another denture resin polymerized by either hot water bath or microwave energy and subjected to repeated microwave irradiation at 345 W for 6min did not show any significant distortion. Therefore, wattage of microwave disinfection seems to be more critical than irradiation time for these resin properties.

Surface roughness of the tested materials was affected by the second disinfection with Protocol 1. Both Onda Cryl and QC-20 resins displayed a reduction of Ra values indicating that the resin surface was smoothed by microwave irradiation after two disinfection procedures. This result was previously shown by Sartori et al. (11) and would indicate an undesirable effect of Protocol 2 on the resin surface as the ideal microwave disinfection protocol should be inert to the material properties.

In summary the results of this study suggest that microwave irradiation at 690 W for 6 min promoted overall damage to both types of denture resins after two disinfection procedures, but the magnitude of changes would not affect clinical service. In general, Onda Cryl resin had greater changes of Ra and internal adaptation than QC-20. It is possible, however, that additional effects may occur after prolonged use of microwave irradiation at 690 W for 6 min, and a lower wattage would be safer to properly disinfect dentures and maintain their physical properties.

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