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The Use of Microwave Energy in Dental Prosthesis

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1. Introduction

Acrylic resins are used as denture base materials since 1937 (Craig, 1993) and heat-cured Poly(methyl-methacrylate) (PMMA) (Lay et al., 2004) composed by methyl methacrylate monomers chains is the most popular of them. Virtually, dentures are constructed from conventional polymer/monomer (Lay et al., 2004) processed by heat water-bath system and compression molding technique (Ganzarolli et al., 2002). It is prepared by mixing the monomer and polymer in a specific ratio, resulting in a dough mass that is packed and pressed in a flask for polymerization (Ganzarolli et al., 2007). Addition polymerization of PMMA requires the activation of the initiator (benzoyl peroxide) to provide free radicals. Polymerization takes place as the free radicals open the double bonds of the methyl methacrylate, creating a chain reaction where the monomer attaches to polymer free radicals (Bartoloni et al., 2000). When the polymerization reaction is activated by heat, the monomers form polymeric chains joined by high energy linkings (crossed-links) and this reaction would finish when all monomers have supposal been reacted (Machado et al., 2004).

Although water-bath polymerization is extensively used to process PMMA, new resins and processing methods have been proposed in order to obtain better physical properties and to simplify the technique (Souza Jr. et al., 2006). Heating curing, chemical curing by pouring technique, light curing and microwave curing resin have been extensively studied for denture base processing (Harman, 1949; Nishii, 1968; Jerolimov et al., 1989; Urabe et al., 1999).

Polymerization of heat-cured PMMA is usually carried out in a temperature-controlled water bath for at least 9 hours. However, the use of microwave energy to polymerize PMMA decreases the time to three minutes only, producing acrylic resin bases with the same quality as those polymerized by water bath technique (Nishii, 1968; Kimura et al., 1983; Hayden, 1986; Jerolimov et al., 1989; Del Bel Cury et al., 1994; Rizzatti-Barbosa et al., 1995; Braun et al., 1988; Ganzarolli et al., 2002; Yunus et al., 2005; Rizzatti-Barbosa et al., 2009). The microwave polymerization technique has advantages such as less equipment is required (Schnieder et al., 2002), the method is fast and clean, the final product has the same quality of physical properties, and it presents better accuracy of fit, resulting in improvement adaptation of denture base (Rizzatti-Barbosa et al., 1995; Rodrigues-Garcia et al., 1996; Compagnoni et al., 2004; Shibayama et al., 2009). The advantages of microwave heating over conventional heating are: (1) the inside and outside of substance are almost equally heated,

and (2) temperature rises rapidly (Lai et al., 2004). Microwave energy acts on the monomer promoting an uniform and immediate heating of the polymer mass (Machado et al., 2004), that activates the decomposition of benzoyl peroxide, the reaction initiator, and quickly yields free radicals for the polymerization process (Sarac et al., 2005), which decreases in the same proportion as polymerization increases (Compagnoni et al., 2004).

Polymerization of PMMA by microwave energy is possible because methyl methacrylate (MMA) is a polar liquid at room temperature, and microwaves create an electromagnetic field inside microwave oven that allows the MMA molecules to orient themselves at a frequency of 2450 MHz (Sanders et al., 1991). Numerous polarized molecules are flipped over rapidly and generate heat due to molecular friction. Because of this, microwave heating is independent of the thermal conductivity; therefore, curing cycles involving the application of rapid heat may be used without the development of a high exothermic temperature.

The use of microwave energy was first reported in 1968 by Nishii as an alternative PMMA processing method and has become increasingly popular as to conventional water-bath processing (Schnieder et al., 2002). Several studies showed that physical properties of denture base resins polymerized with microwave energy or by heat water bath (conventional method) exhibited similar behavior being both of methods adequate to be used in denture acrylic resins fabrication (Kimura et al., 1983; Kimura et al., 1984; Kimura et al., 1987). Some studies reported that it is possible to polymerize acrylic resin in a very short time using microwave energy, however the metal flask must be substituted by the fiber-reinforced plastic (FRP) (Kimura et al., 1983, 1984 and 1985; Reitz et al., 1985; Rizzatti-Barbosa et al., 1995).

Since that, several studies have been investigated different properties of acrylic resin when processed by microwave energy. In Brazil, the first microwave research was reported in 1994 by Del Bel Cury et al., who investigated physical properties of acrylic resin processed by microwave energy compared to water bath. Their results showed differences among the resins that were attributed to the composition of acrylic resins.

2. Solubility, residual monomer and water sorption

The solubility is a property of acrylic resin, representing the not reacted substances releasing (residual monomer, plasticizers and initializers). It is characterized as an undesirable property of resins, since they should be insoluble in oral fluids. Residues releasing from a polymerized resin base can promote tissular reactions in users of prosthesis (Machado et al., 2009). From this point of view, the degree of conversion is one of the most important characteristic of resin, on account of the high residual monomer levels that could be unreacted. Its presence has an adverse effect on physical and mechanical properties (Yunus et al., 1994) as well as on the biocompatibility (Ilbay et al., 1994). Acrylic resin also presents water sorption that is directly related to the polar properties of resin molecules, the physical process of water diffusion through intermolecular space (Takahashi et al., 1998), and the amount of residual monomer in the polymerized mass (Wong et al., 1999). Thus, polymerization degree is directly related to resin's ability of absorbing water (Meloto et al., 2006). Polymerization takes place as the free radicals open the double bonds of the methyl-methacrylate, creating a chain reaction where the monomer attaches to polymer free radicals. The degree of monomer conversion to polymer structure of PMMA is a measure of the carbon double bonds ($C=C$) converted into carbon single bonds ($C-C$) (Bartoloni et al., 2000).

According to Azzarri et al. (2003), from the appropriate selection of power and the resin’s curing time, it is possible to optimise the level of residual monomer and a low cytotoxicity keeping at the same time better mechanical properties. Because of the quick and instantaneous heating, the polymerization of monomers could be damaged by the microwave energy. However, classical studies have been shown that microwave-polymerized acrylic resin presents lower or the same residual monomer levels relative to conventionally polymerized resins (McCabe & Basker, 1976; Austin & Basker, 1980; Austin & Basker, 1982; Huggett et al., 1984; DeClerck, 1987; Truong & Thomasz, 1988; Al Doori et al., 1988; Sadamori et al., 1994; lbay et al., 1994; Yunus et al., 1994; Shlosberg et al., 1989; Jacob et al., 1997). Other researches showed resin polymerized by microwave energy presented similar solubily, residual monomer or water sorption levels than conventional or fast polymerization process.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Urban et al. (2007)	Four hard chair-side reline resins (Duraliner II-D, Kooliner-K, Tokuso Rebase Fast-TRF and Ufi Gel hard-UGH) (short and long polymerization cycles) One heat-polymerized denture base resin (Lucitone 550-L) (short and long polymerization cycles) Immersion in hot water	High performance liquid chromatography, expressed as a percentage of residual monomer.	Statistical differences in residual monomer percentage were found among all materials (K >D >UGH > LLong >TRF > LShort). The reduction in residual monomer promoted by water bath and microwave post-polymerization treatments could improve the mechanical properties and biocompatibility of the relining and denture base materials.
Meloto et al. (2006)	Vipi Cril heat-polymerized acrylic resin (73°C for 9 h) and Vipi Wave microwave resin (20 min/90 W and 5 min/450 W)	Specimens (m1) were stored in distilled water at 37 ± 1°C during 30 days (m2), and weighed. Water sorption (g/cm3) was calculated using the formula: WS = (m2 - m1)/ V.	No difference was found between the group fabricated using water bath and microwave polymerization.
Machado et al. (2004)	Vipi Cril heat-cured acrylic resin (water bath - 74 ± 1 °C for 9 h; Microwave oven – 500 W/ 3 min.)	Solubility test and percentile solubility	The association between polymerization by microwave irradiation and mechanical polishing showed lower percentile solubility, indicating lower residual substances releasing.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Lai et al. (2004)	PMMA denture base polymer (Optilon-399) – (water-bath at 70 8C for 9 h; resin blocks was processed at 80, 160, 240, and 560 W for 15, 10, 7, and 2 min, separately + additional 2 min at 560 W.	Internal temperature – Thermocouples. Solubility – samples weigh percentage of after specific treatment.	Large difference in the curing temperature was observed. The results of the temperature measurement and the solubility analysis indicated that a microwave oven for curing resin was much faster than a conventional water-bath, and the degree of curing also increased a little. Microwave energy can efficiently polymerize and cure denture base polymer from the results of insoluble weight percent and the curing temperature.
Phoenix et al. (2004)	6 commonly used polymethyl methacrylate denture base resins. ADA Specification No. 12. Thermal assessments (differential scanning calorimetry and dynamic mechanical analysis).	Sorption and solubility	The microwaveable resins displayed better results than other denture base resins included in the investigation.
Azzarri et al. (2003)	Four different conditions of power and curing time	Release of residual monomer in water was evaluated by spectrophotometric method up to 24 h.	It is possible to optimise the level of residual monomer and a low cytotoxicity keeping from the appropriate selection of power and time of curing of the resin.
Oliveira et al. (2003)	Acron MC – 500W/3m or 4.5m. One simple flask centrally placed on the turning plate; two flasks, one in the centre and the other peripherally placed in the plate; two flasks centrally, one above and the other below.	Monomer levels - spectrophotometry at 206 nm.	Monomer release was affected by the position of the flask.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Bartoloni et al. (2000)	Lucitone 199® (conventional long-cure), Ac-celar 20® (rapid cure), and Acron MC® (microwave cure)	Fourier transform infrared spectrometry (FTIR)	All curing methods obtained similar degrees of conversion determined by FTIR.
Blagojevic et al. (1999)	TS1195 ; Acron MC; Biocryl NR. Microwave oven for 3 min at 600 W and hot-water bath for 14 h at 70 °C followed by a 3h terminal boil.	Gas liquid chromatography.	General trend suggested that the water-bath method enhanced the degree of polymerization resulting in a lower level of residual monomer. Residual monomer was considerably lower for TS1195, Acron MC and Biocryl NR following water both polymerization.
Del Bel Cury et al. (1994)	Acrylic resins: Acron MC (microwave – 500W/3m); Lucitone 550 (water bath – 73oC/90m); Ortho-Class (self polymerized).	Water sorption and solubility – load of samples	There were differences among tested materials that can be resulted from composition and polymerization methods.

Table 1. Studies on solubility, residual monomer and water sorption of microwaved resin

3. Porosity and color stability

Porosity has been attributed to a variety of factors such as air entrapped during mixing, monomer contraction during polymerization, monomer vaporization associated with the exothermic reaction, and the presence of residual monomer (Keller & Lautenschlager, 1985; Wolfaardt et al., 1986). According to Tager (Tager, 1978) porosity is a property of solids that relates to their structure and is expressed in the presence of voids (pores) between separate grains, layers, crystals, and other elements of a coarse structure of a solid. This definition emphasizes the fact that the concept of porosity can be applied to solids, and that pores are spaces not between molecules, but between super molecule structures. Other authors (Taylor, 1941; Sweeney et al., 1942;) demonstrated that insufficient mixing of monomer and polymer, processing temperatures higher than 74°C, packing of the mold, and inadequate compression on the flask may cause porosity in denture base resin. Depending on polymerization conditions, up to 11% porosity has been observed associated with decreased mechanical properties and poor esthetics (Keller & Lautenschlager, 1985) and the potential harboring of organisms and retention of fluids (Davenport, 1970; Compagnoni et al., 2004). Irregularities and porosities present on denture surfaces offer a favorable niche to retain stain and bacterial biofilm, and because of this denture base polymers are susceptible to color shifting. It depends not only of the polymerization method but also on the chemical characteristics of the material (Polyzois et al., 1999). Considering the processing methods for

acrylic resins, some authors (Austin et al., 1982; May et al.,1992) have stated that polymerization for short period of time promotes higher color instability. Porosity and its consequences have been studied to resin processed by microwave energy (Reitz et al., 1985; Wolfaardt et al., 1986; De Clerck, 1987; Al Doori et al., 1988; Truong & Thomasz, 1988; Levin et al., 1989; Shlosberg et al., 1989; Alkhatib et al., 1990; Bafile et al.,1991; Sadamori et al., 1994; Ilbay et al.,1994;) and some authors verified that it depends on the base thickness (Sanders et al., 1987) or the selection of the material, despite of the microwave processing. (Yannikakis et al., 2002). Prevalent studies on porosity and its consequences are listed on Table 2 and show similar results when comparing microwave and water bath or light cure processing.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Rizzatti-Barbosa et al. (2009)	Water bath-cured resin (Vipi-Cryl) - (74° C for 9 hours) Microwave-cured resin (Vipi-Wave) - (90 W for 13 minutes + 450 W for 5 minutes)	Solution of permanent black ink for 12 hours. Number of pores per area.	Microwave curing is not a factor that alters surface superficial porosity.
Assunção et al. (2009)	Heat cured resin (Microwave polymerization - 500 W for 3 minutes; water bath - 74°C for 9 hours)	Spectrophotometer that measured visible ultraviolet reflection. Color changes calculated by the Commission Internationale de l'Eclairage system - D65 standard illumination.	The color of denture teeth was not affected by the polymerization methods, as there was no significant difference between microwave and conventional polymerization.
Paranhos et al. (2009)	Microwave-polymerized acrylic resin (after immersion in 0.5% NaOCl, 1% NaOCl, and Clorox/Calgon)	Portable colorimeter (Color-guide 45/0). Color changes (ΔE) were calculated with the use of CIELab color space	No statistically significant differences ($p>0.05$) among the solutions for color teeth stability.
Pero et al. (2007)	Onda-Cryl (microwave: 500 W for 3 min; 90 W for 13 min + 500 W for 90 s; 320 W for 3 min + 0W for 4min + 720 W for 3 min); Classico (water bath: 74° C for 9h). Sample thickness: 2.0 mm; 3.5 mm; 5.0 mm.	Polymers and water (classical sorption method and mercury porosimetry - porosity of a sorbet is estimated quantitatively by total pore volume (W0)).	The influence of microwave polymerization cycle on porosity of acrylic resin appears only on the thinnest specimens (2.0 mm). Water bath polymerization group presented similar porosity results for specimens of all tested thicknesses.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Lai et al. (2004)	PMMA denture base polymer (Optilon-399) – (water-bath at 70 °C for 9 h; resin blocks was processed at 80, 160,240, and 560 W for 15,10, 7, and 2 min, separately + additional 2 min at 560 W. Thickness samples was less than 10 mm.	Pulse echo C-scans - Testech ultrasonic tester (model VI-100) – frequency of 10 MHz / 25.4 mm	The amount of porosity increased with an increase in microwave energy level. It is important to control temperature accurately and ensure correct timing to minimize porosity when microwave polymerization is used.
Compagnoni et al. (2004)	Acrylic resin samples: Onda-Cryl, microwave polymerized (500 W for 3 minutes, 90 W for 13 minutes+500 W for 90 seconds, 320 W for 3 minutes+0 W for 4 minutes+720 W for 3 minutes); Clássico, heat-polymerized (water 74 o C/9h).	Porosity – measurement of the specimen volume before and after its immersion in water. Specimen was weighed in air and in water to calculate percent mean porosity. The absolute density of acrylic resin was used to calculate the percent mean porosity.	No differences in mean porosity were found among resin specimens polymerized by microwave energy. The porosity of microwave-polymerized resin was similar in porosity to the heat-polymerized resin.
Oliveira et al. (2003)	Acron MC – 500W/3m or 4.5m. One simple flask centrally placed on the turning plate; two flasks, one in the centre and the other peripherally placed in the plate; two flasks centrally, one above and the other below.	Porosity - permanent ink and counting the porous in a stereo light microscope.	There is no difference among the groups.
Yannikakis et al. (2002)	Two heat-activated denture base resins (short and long microwave cycle) One conventional (Paladon 65) (water bath cured) One designed for microwave polymerization (Acron MC) 3 mm and 6 mm thickness.	Photographed under a microscope at ×100 magnification. Pore were measured with a digital planimeter. Total area of pores per surface was calculated in percentage form	There are no pores in the group polymerized in water bath. Minor porosity was identified in thin areas and more severe porosity in thicker areas of conventional resin specimens that underwent microwave polymerization. No significant porosity was observed in the resin designed specifically for microwave polymerization. Severe porosity in thicker

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
			areas of conventional resin specimens that underwent microwave polymerization, and no significant porosity in the resin designed specifically for this technique.
Rodrigues Garcia et al. (1996)	Denture bases of conventional acrylic resin (water bath 73oC/ 9 hours) and specific resin for microwave polymerization (500 W/3m). Dentures were relined by addition method.	Porosity (immersion of samples in a solution black - pores were counted / stereo light microscope under magnification of 6.3 x)	Conventional resin cured by water bath or microwaves energy showed the highest number of pores after relining
May et al. (1996)	Seven conventional denture base materials One microwave heat cured denture base material processed with the microwave method. Conditions of accelerated aging to test for color stability.	Color measurements were made before weathering and at 300, 600, and 900 hours.	Color changes occurred after accelerated aging in heat-cured denture base resins and Acron GC microwave acrylic resins processed with the microwave.

Table 2. Studies on porosity and color stability of microwaved resin

4. Hardness, transverse strength, flexural strength, shear bond strength, tensile bond strength, impact strength, roughness, and modulus of elasticity

Curing processes have been modified in order to improve the physical and mechanical properties of those materials, and also to afford the technical work of the professionals. The relationship between the physicochemical characteristics and the final properties of a material are of fundamental importance to obtain a resin with the desired properties. The constituent polymer of the powder exhibits a high average molecular weight and a broad of molecular weight distribution. The powder – liquid ratio determines the time dependence of monomer conversion and the rate of polymerization for the formation of the cross-linked network that grows throughout the chains of the base polymer (Wallace et al., 1994). Both characteristics of the polymerization rate and conversion, are proportional to the concentration of the reactive species as well as to the instantaneous temperature (Urabe et al., 1999). For the microwave-cured acrylic resins, it has been demonstrated that the temperature developed during the reaction is not constant: it increases quickly at the beginning, goes through a maximum and then decays, being able to reach peaks of the order of 150–200 °C, depending on the working conditions (Gourdinne et al., 1979; Jacob et al., 1997). Hence, both the power of the microwave and the time of exposition can be regulated to control in these

systems the rate of polymerization and the conversion degree. The long time of microwaves exposition could enhance the rate of secondary reactions of bond breaking on the pending chains breaking bonds by free radical mechanisms, which would be competitive with the main curing reaction. Properties like hardness, transverse strength, flexural strength, tensile bond strength, and modulus of elasticity, in some studies, are not modified by the longer sample exposition time or by the microwave power, probably because these secondary reactions do not change the cross-link density of the material. Only the impact strength would feel their effect because of the shortening of the pendant chains. The reduction of the impact strength for longer molecules was clearly stated, as well as the influence of the length of the cross-linking agent on the resin mechanical properties (Caycik & Jagger, 1992). Researchers investigated mechanical properties of microwave polymerized resins and showed that acrylic resin processed by microwave energy presented the same characteristics of conventional procedures of processing (Nishii, 1968; Stafford & Handley, 1975; Stafford & Huggett, 1978; Faraj & Ellis, 1979; Gourdinne et al., 1979; Kimuta et al., 1983; Reitz et al., 1985; Hayden, 1986; De Clerck, 1987; Kimura et al., 1987; Truong & Thomasz, 1988; Al-Doori et al., 1988; Al-Mulla et al., 1988; Shlosberg et al., 1989; Levin et al., 1989; Alkhatib et al., 1990; Hogan & Mori, 1990; Al-Hanbali et al., 1991; Smith et al., 1992; Caycik & Jagger, 1992;. Chen et al., 1993; Frangou et al., 1993; Jacob et al., 1997). Studies on mechanical properties also showed similar or better results of conventional or light cured resins (Table 3).

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Faot et al. (2008)	Onda Cryl resin. Microwave processing: (3 min at 360 W, 4-min pause, and 3 min at 810 W; and 6 min at 630 W).	Impact strength: Charpy method. Types and morphology of fractures: all fragments analyzed in morphology, crack propagation angles and microstructure.	Both polymerization cycles are adequate to polymerize the denture resin studied.
Ganzarolli et al. (2007)	Conventional water bath polymerized resin. Microwave polymerized resin. Injection-molded resins.	Transverse strength test - universal machine under axial load, at a crosshead speed of 5 mm/ min. Impact strength test - Charpy's test performed with a 40 kJ/ cm load.	There was no relevant improvement of transverse and impact strength. Microwaveable resin showed similar transverse and impact strengths.
Souza Jr. et al. (2006)	Acrylic resins samples: microwave- (Onda Cryl); visible light- (Triad); water bath polymerized (Clássico). Cobalt-chromium metal bar included in resin samples.	Roughness - profilometer (Surfcorder SE 1700) Knoop hardness - (Kg/ mm²) - microhardness tester (Shimadzu HMV 2000)	The presence of metal did not influence roughness and hardness values of any of the tested acrylic resins

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Tacir et al. (2006)	PMMA conventional acrylic resin. Reinforcing effect of glass fibres.	Fracture resistance and Flexural strength. 3- points of the samples. Universal testing machine	Flexural strength of heat-polymerized PMMA denture resin was improved after reinforcement with glass fibres.
Sarac et al. (2005)	Denture base material (a conventionally molded, heat polymerized resin [Meliodent, M]; an injection-molded, Heat polymerized resin[SRIvocap, I], and a microwave polymerized resin [Acron MC, A]). Repaired with an auto polymerizing acrylic resin (Meliodent). Surfaces treated with chemical etchants: acetone (30 s), methylene chloride (30 sec), MMA (180 sec).	Shear bond strength (MPa): universal testing machine.	Chemical treatment showed improvement on the bond strength of the base materials. Microwave-polymerized acrylic resin showed the lowest shear bond strength compared to the control groups.
Vergani et al. (2005)	Heat-polymerized resin (Lucitone 550) Autopolymerizing reline resins: (Duraliner II, Kooliner, Ufi Gel Hard, and Tokuso Rebase Fast). Postpolymerization by microwave energy (500, 550, or 650 W) for (3, 4, or 5 minutes)	Flexural strength – load measurements (Newtons) / crosshead speed of 5 mm/min using a 3-point bending and span of 50 mm.	Microwave postpolymerization irradiation can be an effective method for increasing the flexural strength of Duraliner II (at 650 W) and Kooliner (at 550 W and 650 W for 5 minutes).
Yunus et al. (2005)	Nylon denture base material (Lucitone FRS); conventional compression-moulded heat-polymerized (Meliodent); compression-moulded microwave-	Flexural modulus; flexural strength: three point bending test.	Flexural modulus of nylon was significantly lower than the three PMMA polymers Flexural strength of nylon was significantly lower than those of Acron MC (microwaved) and

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
	polymerized (Acron MC); injection-moulded microwave polymerized (Lucitone 199) PMMA polymers. Water stored at 37°C/30 day Disinfectant stored for 24 h		comparable with Lucitone 199 (microwaved).
Phoenix et al. (2004)	6 commonly used polymethyl methacrylate denture base resins. ADA Specification No. 12. Thermal assessments (differential scanning calorimetry and dynamic mechanical analysis).	Color stability, flexural stiffness, and hardness.	The microwaveable resins displayed greater stiffness, and greater surface hardness than other denture base resins. Elastomeric toughening agents yielded decreased stiffness, decreased surface hardness, and decreased glass transition temperatures.
Lai et al. (2004)	PMMA denture base polymer (Optilon-399) – (water-bath at 70°C for 9 h; resin blocks was processed at 80, 160, 240, and 560 W for 15, 10, 7, and 2 min, separately + additional 2 min at 560 W. Thickness samples were less than 10 mm.	Hardness - Shimadzu hardness tester (HMV-2000 - 300g/30s - 15 areas along uniformly selected points of surfaces). Flexural strength - MTS dynamic tensile testing machine (Model 810) at a crosshead speed of 1.25 mm/min. Three-point-bending test.	Highly statistical differences in flexural properties were evident in a comparison of processing methods. The size and the volume fraction of the rubber phase are in favor of the water-bath method. Water-bath cured specimens showed better flexural strength and flexural modulus than the microwave-cured specimens. There were no significant differences in the surface hardness and the domain size distribution of the effective rubber phase.
Oliveira et al. (2003)	Acron MC – 500W/3m or 4.5m One simple flask centrally placed on the turning plate; two flasks, one in the centre and the other peripherally placed in the plate; two flasks centrally, one above and the other below.	Hardness test – 12 indentations in the surface of specimen.	There is no difference among the groups.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Azzarri et al. (2003)	Acrylic denture base resin microwave polymerized (samples were prepared in 200, 500, and 800, for 5 and 10 min each side up).	Hardness (Rockwell method) Strength (Charpy method). Young’s modulus of elasticity – technique described by Stafford & Handley (1975) according to ISO 1567.	The mechanical properties of the acrylic denture base resin microwave polymerized depend both on the exposition time and microwave power. From the appropriate selection of power and time of curing of the resin it is possible to obtain the best mechanical properties.
Schneider et al. (2002)	Acrylic resins samples: heat polymerized (Lucitone 199); and Microwave polymerized (Acron MC). Acrylic resin denture teeth: (IPN, SLM, Vitapan, and SROrthotyp-PE). ADA specification n° 15.	Strength until sample fracture – custom alignment device debonded specimens. Cohesive failures - scanning electron microscope.	Type of denture base material and denture tooth selected for use may influence the tensile bond strength of the tooth to the base.
Memon et al. (2001)	Microwave polymerized polyurethane-based denture material processed by an injection-molding technique, a conventional microwave polymerized denture material, and a heat polymerized compression-molded poly(methyl methacrylate) (PMMA) denture material.	Impact strength - Charpy-type impact tester. Transverse strength and the flexural modulus - three-point bending test.	Impact and flexural strengths – microwave polymerized injection molded, offered no advantage over the existing heat- and microwave-polymerized PMMA-based denture base polymer. It has rigidity comparable to that of the microwave-polymerized PMMA polymer.
Polyzois et al. (2001)	Heat-polymerized denture base material repaired with heat polymerized resin. Auto polymerized resin alone. Auto polymerized resin with glass fiber	Fracture force, deflection at fracture, toughness: 3-point bending test.	The most effective was microwave-irradiated, auto polymerized resin reinforced with round wire or monolayer glass fiber ribbon.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
	or wire reinforcement. Auto polymerized resin repairs; heat polymerized resin repairs (with no reinforcement, treated with microwave irradiation after polymerization, with monolayer or multilayer glass fiber reinforcement, and with round or braided wire reinforcement).		
Rached et al. (2001)	Heat-cured acrylic resin (Lucitone 550) – repaired with a microwave acrylic resin (Acron MC) – 500W/3m. Chemical treatments (AC monomer dipping/30 s; acetone dipping/30 s; acetone dipping/15 s + blast of air + AC monomer dipping/15 s) in the cut ends.	Surface texture - scanning electron microscopy. Flexural strength.	Surface treatments affected the bond strength between the two acrylic resins. There are no differences in strength between intact heat-cured denture base material and the same material repaired with microwave acrylic resin.
Blabojevic et al. (1999)	A without crosslinking agents homopolymer (TS1195). A cross-linked microwave resin (Acron MC) (Microwave Panasonic oven with rotating turntable). A cross-linked for water-bath polymerization (Biocryl NR) (Conventional water bath). An autopolymerizing reline:repair material (CroForm).	Indentation hardness – Wallace hardness tester Model H6B:SA:C Impact strength – Zwick pendulum impact model 5102 with 0.5 J pendulum.	Microwaving of autopolymerizing resin improved analyzed mechanical properties.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Polyzois et al. (1995)	Denture base resins repaired (standard heat activated polymerising resin, a denture base resin especially formulated for microwave activated polymerisation, auto polymerizing resin). Conventional water bath; microwave curing, and auto polymerized resin repairs.	Transverse Bend impact tests	The transverse strength, and impact resistance of the resin specimens repaired with microwave irradiation were generally superior to specimens repaired by using a water bath curing cycle or the use of an autopolymerising resin.
Yunus et al. (1994)	Acrylic resin repair material bench-cure, hydroflask-cure and microwave irradiation cure.	Repair strength.	On the three methods, polymerization using microwave energy resulted in the strongest repair.
Ilbay et al. (1994)	Twenty-one different polymerization methods were used by varying radiation power and curing time. (3 min at 550 W)	Vickers hardness test transverse load transverse deflection	Resin cured by microwave energy is more resistant to mechanical failure than conventionally cured acrylic.
Del bel Cury et al. (1994)	Acrylic resins: Acron MC (microwave – 500W/3m); Lucitone 550 (water bath – 73°C/90m); Ortho-Class (self polymerized).	Transverse strength and maximum deflection – assay machine in three points (Instron 125) 5mm/m. Impact – Charpy assay.	There were differences among tested materials that can be resulted from composition and polymerization methods.

Table 3. Studies on hardness, transverse strength, flexural strength, shear bond strength, tensile bond strength, impact strength, roughness, and modulus of elasticity of microwaved resin.

5. Base adaptation, dimensional alteration, artificial tooth movement, and teeth occlusion

Considering dimensional alteration of denture or bases resin, when conventional water bath and microwave energy were compared, some authors (Reitz et al., 1985; Levin et al., 1989; Uchida et al., 1989; Takamata et al., 1989; Al-Hanbali et al., 1991; Nelson et al., 1991; Wallace et al., 1991; Sanders et al., 1991; Barbosa et al., 2002; Keenan et al., 2003) found no difference between the two techniques; also, these results are not in agreement with others (Sanders et al., 1991; Nelson et al, 1991). Sanders et al. (1991) observed in their study that microwave

polymerization provided a lower degree of artificial tooth movement, while Nelson et al (1991) reported a greater degree of tooth positional changes when microwave polymerization was employed. Although different investing mediums or polymerization techniques, have been compared (Reitzet al., 1985; Levin et al. 1989; Nelson et al., 1991; Turck & Richards, 1992) the authors could not identify studies published concerning the outcomes provided by the combination of different flasking methods and polymerization techniques. Dimensional changes and distortion of the denture due to the investing stone mold and the heating of acrylic resin can promote tooth movement and, consequently alterations in the occlusal contacts and occlusal vertical dimension (OVD). (Rizzatti-Barbosa et al., 2006; Rizzatti-Barbosa et al., 2005). Acrylic resin processing methods do not avoid displacement of artificial teeth during denture inclusion and processing, which might increase occlusal vertical dimension due to production of premature contacts (Barbosa et al., 2002). It is hence necessary to adjust the oclusal surface of artificial teeth, which alters the occlusal anatomy, especially of posterior teeth (Lai et al., 2004). In addition, these alterations may cause mucosal injuries and affect the functionality of the prostheses, thus causing damage to the stomatognathic system, temporomandibular disorders and discomfort to the patient (Yagi et al., 2006). Simultaneous polymerization of maxillary and mandibular complete dentures with the teeth in occlusion by means of a special double flask (DF), has been described as a more rapid and simple method for investing and polymerizing prostheses (Rizzatti-Barbosa et al., 2005). This inclusion technique was claimed to save time and decrease occlusal alteration during denture processing (Meloto et al., 2006). It may be an easier and faster method of investing and polymerizing prostheses. The first designed DF was a metal copper-aluminum flask (DMF) for simultaneous polymerization of both maxillary and mandibular prostheses in a warm water bath (Dental VIPI Ltd, Pirassununga, Brazil). The double polyvinyl chloride flask (DPVCF) (Dental VIPI Ltd, Pirassununga, Brazil) was developed following the same principles for simultaneous processing of both dentures in occlusion through microwave energy heating (Rizzatti-Barbosa et al., 2005). This new technique associating acrylic curing with microwave energy can be considered a clean method that saves time, reduces occlusal interferences, preserves the teeth occlusion, and maintains the OVD. (Rizzatti-Barbosa & Ribeiro-Dasilva, 2009). In the classical literature, some data on the acrylic resins morphology alteration can be found (Huggett et al., 1984; Polyzois et al., 1987; Chen et al., 1988; Jagger, 1996). Some controversial results about microwave processing resin are shown on table 4, where the authors compared microwaving technique with other and related the results of teeth positioning, dimensional alteration, vertical measurement of dentures, etc.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Negreiros et al. (2009)	Clássico (Conventional long cycle in water bath). Onda-Cryl (Microwave energy). QC-20 (Fast cycle in boiling water). Post pressing process.	The linear distances - STM microscope (right premolar to left premolar; right molar to left molar; right incisor to right molar; left incisor to left molar).	Microwave polymerization was similar to that of the conventional cycles in water bath post-pressing time had no relevant effect on tooth movement.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Schibayama et al. (2009)	Dentures processed with: Acrylic resin for water bath polymerization (QC20); Acrylic resin for microwave polymerization (Acron MC). Flasking: (1) adding a second investment layer of gypsum and conventional water bath polymerization, (2) adding a second investment layer of gypsum and polymerization with microwave energy, (3) adding a second investment layer of silicone and conventional polymerization, and (4) adding a second investment layer of silicone and polymerization with microwave energy.	Comparison of the artificial tooth position changes following flasking and polymerization of dentures - linear microscope.	The use of a silicone investment layer when flasking complete dentures resulted in the least positional changes of the artificial teeth regardless of the polymerization technique.
Faot et al. (2008)	Onda Cryl resin Microwave processing: (3 min at 360 W, 4-min. pause, and 3 min at 810 W; and 6 min at 630 W).	Accuracy of fit: 3 points at the right and left ridge crests and at the midline on the posterior palatal seal for each denture base.	Both polymerization cycles are adequate to polymerize the studied denture resin.
Pavan et al. (2005)	Dentures in acrylic resin (Clássico - water bath processing). Storage in water for 30 days. Microwave disinfection: 3 min at 500 W; and 10 min at 604 W.	Dimensional accuracy along the posterior palatal border of maxillary acrylic resin denture bases.	Treatment in microwave oven at 604 W for 10 min produced the greatest discrepancies in the adaptation of maxillary acrylic resin denture bases to the stone casts.
Rizzatti-Barbosa et al. (2005)	Pairs of dentures processed by microwave energy and flasked in occlusion in double flasks.	Occlusal inclination of mandibular and maxillary artificial denture molars.	Dentures double flasking and microwave curing save time, reduce occlusal alteration, and reduce time exposure of dentures.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Lai et al. (2004)	Microwaved resin blocks, processed at 80, 160, 240, and 560 W for 15, 10, 7, and 2 min / 70°C for 9 h.	The morphology of the specimens after staining with osmium tetroxide was examined by transmission electron microscope.	Highly statistical differences in morphology favor of the water-bath method.
Botega et al. (2004)	Retangular samples and half-discs of microwaved-cure acrylic resin (Acron MC). 1, 2, 4, and 6 flasks simultaneous processing. Polymerization time starting in 3min/450W - adjustmentsbased on monomer release.	Monomer release: spectrophotometer Beckman DU-70. Knoop hardness: Shimadzu HMV 2000 hardness tester. Porosity: black inch immersion and count pores in microscope.	The number of flasks does not interfere with polymerization, knoop hardness, and porosity.
Phoenix et al. (2004)	6 commonly used polymethyl methacrylate denture base resins. ADA Specification No. 12. Thermal assessments (differential scanning calorimetry and dynamic mechanical analysis).	Adaptation denture bases.	The microwaveable resins displayed better adaptation than other denture base resins included in this investigation.
Keenan et al. (2003)	Identical maxillary denture bases in: PMMA (Trevalon - Compression flask - hot air oven); microwave polymerized resin (AcronMC Injection flask - 600-W microwave oven/3m); PMMA (Trevalon - Injection flask - hot air oven); resin injection flasks (Microbase Injection flask - 600-W microwave oven/ 6m)	Pre and post treatment intermolar width - traveling microscope. Pre and post treatment vertical dimension of occlusion - points on the superior and inferior members of the articulator.	All injection molding methods produced dentures with a slightly smaller increase in vertical dimension of occlusion. Both microwave polymerization methods produced maxillary complete dentures with a greater reduction in intermolar width.
Ganzarolli et al. (2002)	Heat-cured acrylic resin (Classico); two microwave-cured acrylic resins (Acron MC and Onda Cryl). Water storage.	Adaptation - weight of silicone impression material between the base and the master die.	Interaction of type of material and cooling procedure has effect on the final adaptation. Water storage was not a source of variance on the final adaptation.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Barbosa et al. (2002)	Maxillary dentures polymerization with different cycles by microwave radiation.	Changes in occlusal vertical dimension: average in articulator pin opening	There was no difference between the groups polymerized by the microwave method and the control group
Del Bel Cury et al. (2001)	Two microwave-cured acrylic resins (Acron MC and Onda Ceryl). Gypsum moulding technique or silicone gypsum moulding technique.	Residual monomer – 24 or 48 h over a period of 288 h. Knoop hardness – after 24, 48, 72 h and 30 days. Transverse strength – 48 h of water storage.	Storage periods and moulding technique did not influence Knoop hardness. The type of mould did not affect tranverse strength. The acrylic resins differed from each other for all properties, regardless of the type of mould.
Braun et al. (2000)	Samples of acrylic resins (Classico, Lucitone 550, Acron MC). Water bath (long cicle), water bath (short cicle), and microwave energy (500W/3 m). Water sorption – 30 days.	Linear dimensional alteration – pre and post water sorption period (linear microscopy).	All samples presented expansion after water sorption period.
Wong et al. (1999)	Dentures polymerization by 3 processing techniques (dry and wet heat; different rates of cooling).	Dimensional changes - traveling microscope. Water sorption - electronic balance (water uptake).	Water uptake after deflasking was low. The dentures did not reveal differences in shrinkage at water saturation. Oven-processed and water bath processed acrylic resin dentures showed similar dimensional shrinkage at water saturation.
Sadamori et al. (1997)	Acrylic resin dentures. Different thickness. Processing: conventional method, fluid resin technique, and microwave curing method.	Residual monomer – gas liquid chromatography. Dimensional accuracy, and resin stability.	Dimensional accuracy and stability of acrylic resin dentures could be influenced by the processing method. The thickness of the bases, and the shape and size of the dentures influenced on dimensional changes.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Rodrigues Garcia et al. (1996)	Denture bases of conventional acrylic resin (water bath 73°C/ 9 hours) and specific resin for microwave polymerization (500 W/3m). Dentures were relined by addition method.	Accuracy - weight of an impression material put between the denture base and cast die.	Conventional resin cured by water bath or microwave energy showed better adaptation.
Rizzatti-Barbosa et al. (1995)	Dentures in acrylic resin: Acron MC (microwaved - 500W/3m); Lucitone 150 (water bath - 72°C/9h). Water Storage for 30 days.	Posterior palatal fit weight and measurement of impression material between the denture base and master cast.	There were no difference among the resins, polymerization methods and water storage period.
Salim et al. (1992)	Rectangular acrylic resin specimens processed by three methods: a conventional method, the SR-Ivocap system, and a microwave curing method.	Dimensional accuracy - change of the distance vector V (calculated by means of measurements of the distances between fixed points on specimens).	SR-Ivocap system exhibited less dimensional change. SR- Ivocap system might produce more accurate denture base than conventional and microwave curing methods.

Table 4. Studies on base adaptation, dimensional alteration, artificial tooth movement, and teeth occlusion of microwaved resin

6. Studies about the effects of microwave disinfection

Bacterial and yeast plaque on dentures may lead to serious infections, such as systemic candidal infection, particularly in patients who have debilitating diseases (Montagner et al., 2009). The use of microwave energy to disinfect dentures has been suggested to overcome the problems associated with denture cleaning. Microwave energy was introduced in 1985 for sterilization of nonautoclavable dental materials. It was shown that exposed to microwave energy for 10 minutes can kill microorganisms if the denture is attached to a three-dimensional rotating device (Rohler & Bulard, 1985).

Lining materials have been found to be more prone to microbial adhesion than acrylic resin base materials and have been demonstrated to interact with oral microorganisms because of their surface texture and the physical/chemical affinity between the materials. Surface roughness of the resilient liners may differ among materials (Zissis et al., 2000; Jin et al., 2003), and rougher surfaces enhance the adhesion of microorganisms onto resilient lining materials (Bulad et al., 2004) that may allow fungal growth (Brosky et al., 2003). The microorganisms from the plaque on the denture surface may expose patients and dental personnel to infection (Witt et al., 1990).

Denture disinfection has been recommended as an essential procedure for preventing cross-contamination and the maintenance of a healthy oral mucosa. The use of microwave

irradiation to disinfect dentures and reliners has been suggested (Burns et al., 1990; Polyzois et al., 1995; Webb et al., 1998; Baysan et al., 1998; Thomas et al., 1995; Baysan et al., 1998; Webb et al., 1998) and stimulated as a disinfection model (Fitzpatrick et al., 1978; Lamb et al., 1983; Rohler et al., 1985; Jeng et al., 1987; Friedrich et al., 1988; Najdovski et al., 1991; Arikan et al., 1995; Atmaca et al., 1996; Lin et al., 1999; Kedjarune et al., 1999; Yeo et al., 1999; Nikawa et al., 2000; Jin et al., 2003; Pavarina et al., 2003; Gonçalves et al., 2006; Setlow, 2006; Gonçalves et al., 2007). Since that, researches have been developed in order to ensure the safe use of microwaving disinfection (Table 5).

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Sanita et al. (2008)	Dentures incubation (37 °C/ 48 h): (<i>C.albicans</i> , <i>C.dubliniensis</i> , <i>C.krusei</i> , <i>C. glabrata</i> and <i>C.tropicalis</i>). Dentures microwaved (650 W/3 min).	Microbial growth on the plates.	Microwave irradiation for 3 min at 650 W resulted in sterilisation of all complete dentures.
Machado et al. (2009)	2 hard chairside reline resins (Kooliner, DuraLiner II); 1 heat-polymerizing denture base resin (Lucitone 550). Microwave and chemical disinfection of samples.	Vickers hardness. Roughness measurements – profilometer (diamond stylus tip radius of 2 µm).	Disinfection by microwave irradiation did not adversely affect the hardness of all materials evaluated. Roughness varied among materials and the effect seems to be material dependent.
Novais et al. (2009)	Auto polymerised denture reline materials (Kooliner). Conventional heat polymerized denture base resin (Lucitone 550).	Porosity – after polymerization; after two cycles of microwave disinfection; after seven cycles of microwave disinfection; after 7 days storage in water at 37°C. Number of pores - Scanning electron microscopy at magnification x 100.	Differences in the porosity amongst the materials and for different experimental conditions were observed following microwave disinfection.
Paranhos et al. (2009)	Microwave polymerized acrylic (Onda-Cryl). Immersed in 0.5% NaOCl, and 1% NaOCl.	Color stability – portable colorimeter. Surface roughness – Surftest SJ-201P surface analyzer (resolution of 0.01 µm). Flexural strength – universal testing machine (50 kgf load cell / crosshead speed of 1 mm/min).	Microwave showed similar results after treatment in all groups.
Dovigo et al. (2009)	70 water bath polymerized complete dentures.	Cultures were interpreted as positive or negative growth after disinfection	Microwave irradiation for 3 minutes at 650 W produced sterilization

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
	Inoculated – <i>Staphylococcus aureus</i> , <i>Pseudomona aeruginosa</i> , <i>Bacillus subtilis</i> , and incubated for 24 hours at 37° C. Microwave irradiation at 650 W for 3 minutes.	treatment.	of complete dentures contaminated with <i>S. aureus</i> and <i>P. aeruginosa</i> . Dentures contaminated with <i>B. subtilis</i> can be disinfected by microwave irradiation after 3 and 5 minutes at 650 W.
Montagner et al. (2009)	Microwave-cured acrylic resin specimens contaminated with <i>Candida albicans</i> antifungal action of different disinfection agents (2% chlorhexidine solution / 10 min; 0.5% sodium hypochlorite / 10 min; modified sodium hypochlorite / 10 min; effervescent agent / 5 min; hydrogen peroxide 10 v / 30 min).	Culture media turbidity - spectrophotometrically according to the transmittance degree (the higher the transmittance the stronger the antimicrobial action).	Sodium hypochloritebased substances and hydrogen peroxide are more efficient disinfectants against <i>C. albicans</i> than 2% chlorhexidine solution and the effervescent agent.
Sartori et al. (2008)	Denture base resin disinfection procedures performed twice: Chemical disinfection (immersion in 100ppm chloride solution for 24h), and Microwave Disinfection (irradiation at 690 W).	Knoop microhardness dimensional stability - weighing a vinyl polysiloxane film reproducing the gap between resin base and master model.	Knoop microhardness was not modified by any disinfection procedure, but decreased over time. Microwaved denture resin bases had gradual increase of distortion over time.
Mima et al. (2008)	Hard chairside relined resin samples inoculation by <i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i> , <i>Candida albicans</i> , and <i>Bacillus subtilis</i> . Samples microwaved at 650 W for 1, 2, 3, 4, or 5 minutes before serial dilutions and platings.	Colonies on plates were counted after 48 hours of Incubation.	3 minutes of microwave irradiation can be used for acrylic resin sterilization.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Ribeiro et al. (2008)	Three polymethyl methacrylate (PMMA) resins: a conventional water-bath, heat activated acrylic resin (Lucitone 550), rapid polymerizing acrylic resin (QC-20-QC)), and microwave activated acrylic resin (Acron MC-AC). Two cycles of microwave disinfection (650W for 6 min – once, twice and seven times).	Shear bond strength between denture teeth and acrylic resins having different polymerization cycles - knife-edge shear test in a universal test machine (MTS-810).	The shear bond strength between the denture teeth and the acrylic resins Acron MC and Lucitone 550 was not affected by microwave disinfection. After two cycles of microwave disinfection, the shear bond strength of teeth to QC-20 acrylic resin was increased. Seven cycles of microwave disinfection significantly decreased the shear bond strength between teeth and QC-20 acrylic resin.
Pero et al. (2007)	Two heat-activated denture base resins – conventional (Clássico - water bath); designed for microwave polymerization (Onda-Cryl – manufacturing microwave cycle, short microwave cycle and long microwave cycle). Thicknesses - 2.0, 3.5, and 5.0 mm. Immersion in water.	Porosity.	Microwave polymerization cycles and the specimen thickness of acrylic resin influenced porosity. Porosity differences were not observed in the polymerized resin bases in the water bath cycle for any thickness.
Consani et al. (2007)	Maxillary denture base adaptation (Clássico - 74° C for 9 hours). 2 different flasks: closure methods (traditional flask closure and Restriction System flask closure methods). Simulated disinfection in 150 mL distilled water in a microwave oven at 650 W for 3 minutes.	3 transverse cuts on denture bases: distal of canines, mesial of first molars, and posterior palatal region. Measurements of desadaptation: optical micrometer at 5 points.	Simulated disinfection by microwave energy improved denture base adaptation.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Seo et al. (2007)	Lucitone 550 denture bases (2- and 4-mmthick). Intact and autopolymerizing resin relined. 1 cycle of microwave disinfection (650W/6min); daily microwave disinfection for 7 days.	Dimensional stability – area between 5 removable pins on the standard brass cast measured with a Nikon optical comparator, before and after treatment.	Microwave disinfection produced increased shrinkage of intact specimens and those relined.
Pavan et al. (2007)	Four soft lining materials (Molloplast-B, Ufi Gel P, Eversoft, Mucopren soft). Microwave oven for 3 minutes at 500 W. Disinfectant solutions for 10 minutes.	Hardness - Shore A durometer.	Application disinfection cycles did not change the Shore A hardness values for the materials.
Sartori et al. (2006)	Denture resin bases. Chemical disinfection. Microwave disinfection. Twice with a 7-day interval between them.	Internal adaptation: weighing a vinyl polysiloxane film reproducing the gap between the resin base and the master model.	Microwave disinfection had gradual increase of misfit bases immersed in chloride solution did not differ from the control group.
Silva et al. (2006)	Complete resin dentures. Inoculated by <i>Candida albicans</i> , <i>Streptococcus aureus</i> , <i>Bacillus subtilis</i> , and <i>Pseudomonas Aeruginosa</i> . Disinfection by microwave irradiation at 650 W for 6 minutes.	Effectiveness of microwave disinfection: count of the number of colony-forming units.	Microwave irradiation for 6 minutes at 650 W produced sterilization and disinfection of complete dentures.
Moura et al. (2006)	Classico (water bath - 9 h at 74° C). Onda Cryl (Microwave energy 3 min at 360 W + 4 min pause + 3 min at 810 W). Infection - (<i>Candida albicans</i> , <i>Candida tropicalis</i> , <i>Candida dubliniensis</i> , <i>Candida glabrata</i>).	Roughness – profilometer. Surface free energy – contact angle of a sessile drop of water.	The polymerization method, heat versus microwave, did not influence <i>Candida</i> species adherence values. There is no correlation regarding surface free energy, surface roughness and the adhesion of <i>Candida</i> species. Heat polymerized acrylic resin showed highest surface free energy values.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Machado et al. (2006)	Cylindrical (30 x 3.9 mm) resin specimens (Lucitone 199). Reline materials packed in resin. Twice microwave irradiation (650 W for 6 minutes).	Torsional test (0.1 Nm/ min). Torsional strengths (MPa). Mode of failure.	Microwave disinfection cycles do not decrease the torsional bond strengths between the hard relined resins. Disinfection cycles on relined material may be clinically significant and requires further study.
Machado et al. (2005)	Acrylic resin (Lucitone 199). Resilient lining materials (GC Reline Extra Soft and Dentusil). Samples irradiated twice, with 650 W/6 min; samples irradiated daily for 7 total cycles.	To peel the resilient adhesive - screw tensile tester (Sintec 2/G) (visual analyzed of resin interface). Hardness - Shore A durometer (before and after treatment).	Microwave disinfection did not compromise the hardness of either resilient liners or their adhesion to the denture base resin Lucitone 199. The hardness of the Lucitone 550 denture base resin specimens was not affected by either disinfection method evaluated.
Campanha et al. (2005)	6 brands of artificial teeth. Microwave sterilization at 650W for 6 minutes.	Hardness - Vickers diamond indentator.	Two cycles of microwave sterilization did not affect the hardness of most of the acrylic resin denture teeth tested. Microwave sterilization significantly decreased the hardness of acrylic resin artificial teeth.
Pavarina et al. (2005)	Denture base resin (Lucitone 550). Five hard chairside relined resins (Kooliner, Duraliner II, Tokuso Rebase Fast, Ufi Gel Hard, and New Truliner). Microwave disinfection (650W/6 min): two cycles and seven cycles.	Flexural strength (MPa) – 3 point bend fixture in a MTS machine and loaded until failure.	Microwave disinfection do not adversely affect the flexural strength of all tested materials.
Rodrigues Garcia et al. (2004)	Microwave-cured acrylic resin disc shaped samples. 3 cleansing treatments (polident, manipulation pharmacy cleanser, and water).	Hardness. Roughness.	Manipulated cleanser containing sodium perborate increased surface roughness and hardness.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
Seo et al. (2007)	2- and 4-mm-thick denture bases (Lucitone 550). Reline with 2 mm of autopolymerizing resin (Tokuso Rebase Fast, Ufi Gel Hard, Kooliner, or New Truliner).	Dimensional stability – 5 removable pins on the standard brass cast – area (mm) formed by the distance between 5 pins (Nikon optical comparator).	Microwave disinfection produced increased shrinkage of intact specimens and those relined with New Truliner and Kooliner.
Neppelenbroek et al. (2003)	Treatment of 15 denture patients with <i>Candida</i> - related denture stomatitis. Upper denture microwaved (650 W/6 min) three times per week for 30 days; conjunction with topical application of miconazole three times per day for 30 days; antifungal therapy only.	Cytological smears and mycological cultures – after and before treatment (days 15 and 30 follow-up).	Microwaving dentures was effective for the treatment of denture stomatitis.
Banting et al. (2001)	Thirty-four subjects with a positive test for <i>C. albicans pseudohyphae</i> . Subjects in the microwave treatment group – maxillary denture microwaved (850W/1m). Procedure repeated three times. Standard denture soak treatment – liquid disinfect the dentures (.2% chlorhexidine digluconate solution overnight for 14 days).	Infestation of the tissue surface of the maxillary denture; cytological smears.	Patients whose dentures were microwaved have delayed dramatically reinfestation of the denture surface and infection of the adjacent soft tissue. Microwave treatment is not recommended for all dentures and should be used with caution.
Dixon et al. (1999)	Denture base soft liners and heatpolymerized Acrylic resin denture base material. Inoculation with <i>C. albicans</i> . Irradiation in a 60 Hz microwave oven for	Efficacy of microwave irradiation against <i>C. albicans</i> . Effect of irradiation on the materials hardness. <i>C. Albicans</i> growth assessed with streaked blood agar plates and thioglycollate broth.	Five-minute irradiation, while immersed in water, killed all <i>C. albicans</i> present on the materials tested; repeated 5-minute irradiation significantly affected the hardness of only the PermaSoft.

Authors and date	Materials and groups	Methods and measurements	Comments and conclusions
	5minutes (10 - and 15-minute irradiation; repeated 5-minute irradiation cycles).	Shore A hardness material.	

Table 5. Studies about the effects of microwave disinfection

7. Conclusion

The use of microwave energy in the processing of acrylic resin is based on both, classic and recent studies. The observed differences when using microwave or water-bath curing usually are not clinically significant where mechanical properties of microwave and water-bath cured resins are not significant in the resins properties. The frequency and size of porosity in thick specimens could be reduced to 30% by a longer polymerization time at a lower wattage. Microwave curing as a rule, has little effect on the properties of resins when the choice of a suitable power and polymerization time are adequate, reducing porosity or dimensional alteration to a minimum level.

Because it offers some important physical properties as good as conventional processing, along with the advantage of being a quicker and easier method, it should also be considered in processing removable partial dentures or complete dentures, and as a disinfection method of resin prosthesis.

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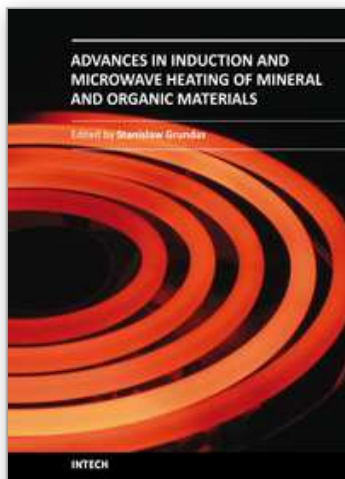
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