Influence of Artificial Accelerated Aging on Dimensional Stability of Acrylic Resins Submitted to Different Storage Protocols

Lucas da Fonseca Roberti Garcia, DDS, MS,[1] Lourenço de Moraes Rego Roselino, DDS,[2] Fabrício Mariano Mundim, DDS, MS,[2] Fernanda de Carvalho Panzeri Pires-de-Souza, DDS, MS, PhD,[2] & Simonides Consani, DDS, MS, PhD[1]

[1] Department of Restorative Dentistry, Dental Materials Area, Piracicaba Dental School, Campinas State University, Piracicaba, Brazil
[2] Department of Dental Materials and Prosthodontics, Ribeirao Preto Dental School, São Paulo University, Ribeirao Preto, Brazil

Keywords
Dimensional stability; acrylic resin; aging; storage; mechanical properties.

Correspondence
Fernanda de Carvalho Panzeri Pires-de-Souza, Faculdade de Odontologia de Ribeirão Preto – USP, Departamento de Materiais Dentários e Prótese, FORP-USP, Avenida do Café, s/n, Bairro Monte Alegre, CEP: 14040–904, Ribeirao Preto – Sao Paulo – Brasil. E-mail: ferpanzeri@forp.usp.br

Accepted: August 25, 2009

doi: 10.1111/j.1532-849X.2010.00611.x

Abstract

Purpose: The aim of this study was to evaluate the influence of artificial accelerated aging on dimensional stability of two types of acrylic resins (thermally and chemically activated) submitted to different protocols of storage.
Materials and Methods: One hundred specimens were made using a Teflon matrix (1.5 cm × 0.5 mm) with four imprint marks, following the lost-wax casting method. The specimens were divided into ten groups, according to the type of acrylic resin, aging procedure, and storage protocol (30 days). GI: acrylic resins thermally activated, aging, storage in artificial saliva for 16 hours, distilled water for 8 hours; GII: thermal, aging, artificial saliva for 16 hours, dry for 8 hours; GIII: thermal, no aging, artificial saliva for 16 hours, distilled water for 8 hours, GIV: thermal, no aging, artificial saliva for 16 hours, dry for 8 hours; GV: acrylic resins chemically activated, aging, artificial saliva for 16 hours, distilled water for 8 hours; GVI: chemical, aging, artificial saliva for 16 hours, dry for 8 hours; GVII: chemical, no aging, artificial saliva for 16 hours, distilled water for 8 hours; GVIII: chemical, no aging, artificial saliva for 16 hours, dry for 8 hours GIX: thermal, dry for 24 hours; and GX: chemical, dry for 24 hours. All specimens were photographed before and after treatment, and the images were evaluated by software (UTHSCSA – Image Tool) that made distance measurements between the marks in the specimens (mm), calculating the dimensional stability. Data were submitted to statistical analysis (two-way ANOVA, Tukey test, $p = 0.05$).
Results: Statistical analysis showed that the specimens submitted to storage in water presented the largest distance between both axes (major and minor), statistically different ($p < 0.05$) from control groups.
Conclusions: All acrylic resins presented dimensional changes, and the artificial accelerated aging and storage period influenced these alterations.

Dimensional stability is an important physical property for acrylic resins, widely used for the manufacture of bases for removable prostheses, to ensure that the denture is able to maintain its shape over a period of time.[1–3] Acrylic resin dimensional stability may be influenced by several factors, such as polymerization techniques in which the internal stresses are produced by different coefficients of thermal expansion of gypsum and acrylic resin,[4] and denture base thickness, which may vary at different sites inside the flask,[5] altering the base adaptation and stability.[6]

Dimensional changes in denture bases result from monomer shrinkage during polymerization and stresses released when the flask cools. The shrinkage due to polymerization reaction is not uniform, being more accentuated in the posterior region of the palate, and it is difficult to compensate after processing.[7] Conversely, distortion results from cooling and removal of the base from the plaster model, both causing the release of stresses induced during processing.[8] Additionally, cleaning systems, the physical behavior of the material, and variations in the environment during service, such as water sorption and pH changes, may contribute to dimensional change.[9] It is common for patients with complete dentures to leave their dentures out at night and store them in water or a mild disinfectant,[9] because dentures are believed to warp or shrink if allowed to dry out,

thereby affecting the clinical fit. Denture-related stomatitis has been shown to be associated with continuous denture wearing,[10] as has poor denture hygiene, the denture base acting as a site for plaque and *Candida albicans* proliferation.[11,12] Mechanical cleansing and leaving dentures out of the mouth at night are considered to be important to keep dentures adequately plaque- and *Candida albicans*-free; however, there are differing opinions as to the value of using chemical cleansers.[9-12]

The dimensional changes associated with the sorption of water during and immediately after processing of acrylic resin denture bases has been well documented,[1-3,13] although dimensional change occurring during processing has been shown to be statistically significant but clinically irrelevant because the changes are too small to affect clinical fit of a prosthesis.[14-16] When acrylic resins are in use, they are submitted to rigorous clinical conditions with alterations in pH, salivary flow, and temperature.[9,13,14] To simulate these conditions, the literature shows different methods to simulate their aging for verifying the behavior of these materials in the long term. Among these, the methods of immersion in solutions such as water, tea, wine, mouthwash, and others are outstanding.[17] There are also cycles of immersion in water at different temperatures alternated with light irradiation,[18] and another method of artificial accelerated aging (AAA) by exposure to UV light and water condensation in 4-hour cycles for 384 hours.[19,20] AAA is achieved in a laboratory environment that indicates the behavior of a material under certain conditions. It is widely used for development and control of different properties of materials.[21]

Thus, the aim of this study was to evaluate the effect of AAA on dimensional stability of two types of acrylic resins, thermally and chemically activated, submitted to different protocols of storage, that simulated the daily cycle of removable prostheses. The tested hypothesis was that prostheses submitted to aging and stored in water would present higher values of dimensional change.

Materials and methods

Specimen preparation

The methodology for preparing the specimens followed a sequence based on the lost-wax casting method. A Teflon matrix with four imprint marks, an internal diameter of 1.5 cm, and thickness of 5.0 mm was used (Fig 1). After internal lubrication with petroleum jelly, heated casting wax (Polidental, Cotia, Brazil) was deposited inside the matrix. After it was totally filled, and with little excess, a flat, clean, polished, and lubricated glass plate was put onto the wax and left there until the surface cooled. Then, the glass plate was removed, and the excess wax was carefully removed with a sharp instrument. Afterwards, the specimens were removed from the matrix. Fifty wax molds were made for each type of acrylic resin (thermally and chemically activated). These molds were included in plaster stone using a metal flask. After the stone setting time, the matrix was removed with hot water.

The two types of acrylic resins (Clássico Artigos Odontológicos Ltda, São Paulo, Brazil) were manipulated in accordance with the manufacturer's recommendations. When the mass reached the plastic phase, the space left by the matrix was filled in with the material. After total condensation of the material, the flask was closed and submitted to pressure. After the curing process, the flask was opened, and excess removed. Therefore, 50 specimens were obtained for each type of acrylic resin and subdivided into ten groups ($n = 10$), according to aging procedure and storage protocol (Table 1). Before treatment, all specimens were photographed one by one, and the captured images were analyzed using software (UTHSCSA – Image Tool, The University of Texas, Health Science Center San Antonio, San Antonio, TX, USA) that made distance measurements (mm) between the markings (major and minor axes) in the specimens (Fig 2).

Artificial accelerated aging and storage period

Twenty specimens of each type of acrylic resin were submitted to AAA (C-UV, Comexim Matérias Primas Ltda, São Paulo, Brazil) under UV light and air-saturated condensed water. The fixed working program was 4-hour cycles of exposure to UV-B light at 50°C and 4-hour cycles of condensation at 50°C for 384 hours, corresponding to a year of clinical use,[22] in agreement with the guidelines recommended by American Society for Testing and Materials (ASTM).[21] After aging, the

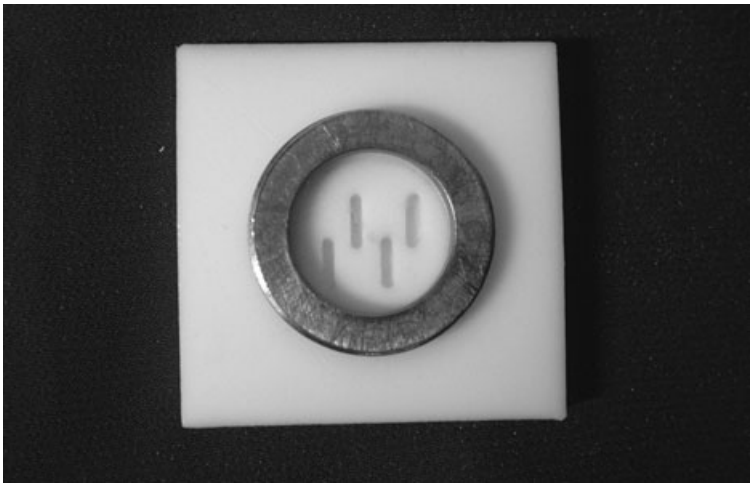

Figure 1 Matrix to manufacture the acrylic resin specimens.

Table 1 Studied groups according to acrylic resin type, aging procedure, and storage protocol

Group	Acrylic resins	AAA	Protocol storage
I	Thermal	+	Artificial saliva for 16 hours, distilled water for 8 hours at 37°C
II	Thermal	+	Artificial saliva for 16 hours, dry for 8 hours at 37°C
III	Thermal	–	Artificial saliva for 16 hours, distilled water for 8 hours at 37°C
IV	Thermal	–	Artificial saliva for 16 hours, dry for 8 hours at 37°C
V	Chemical	+	Artificial saliva for 16 hours, distilled water for 8 hours at 37°C
VI	Chemical	+	Artificial saliva for 16 hours, dry for 8 hours at 37°C
VII	Chemical	–	Artificial saliva for 16 hours, distilled water for 8 hours at 37°C
VIII	Chemical	–	Artificial saliva for 16 hours, dry for 8 hours at 37°C
IX (control)	Thermal	–	Dry for 24 hours at 37°C
X (control)	Chemical	–	Dry for 24 hours at 37°C

(+) Specimens submitted to AAA.
(–) Specimens not submitted to AAA.

specimens were stored as shown in Table 1 for 30 days. The artificial saliva composition is shown in Table 2.

After storage, new measurements were made using Image Tool software. The difference between measures before and after storage was calculated for each studied group and submitted to two-way ANOVA and Tukey test at significance level of $p = 0.05$.

Results

Statistical analysis showed that the specimens submitted to storage in distilled water (odd-numbered groups) presented highest values in the distance between both axes (major and minor), statistically different ($p < 0.05$) from control groups (GIX, GX). Analyzing the two types of acrylic resins, it was found that

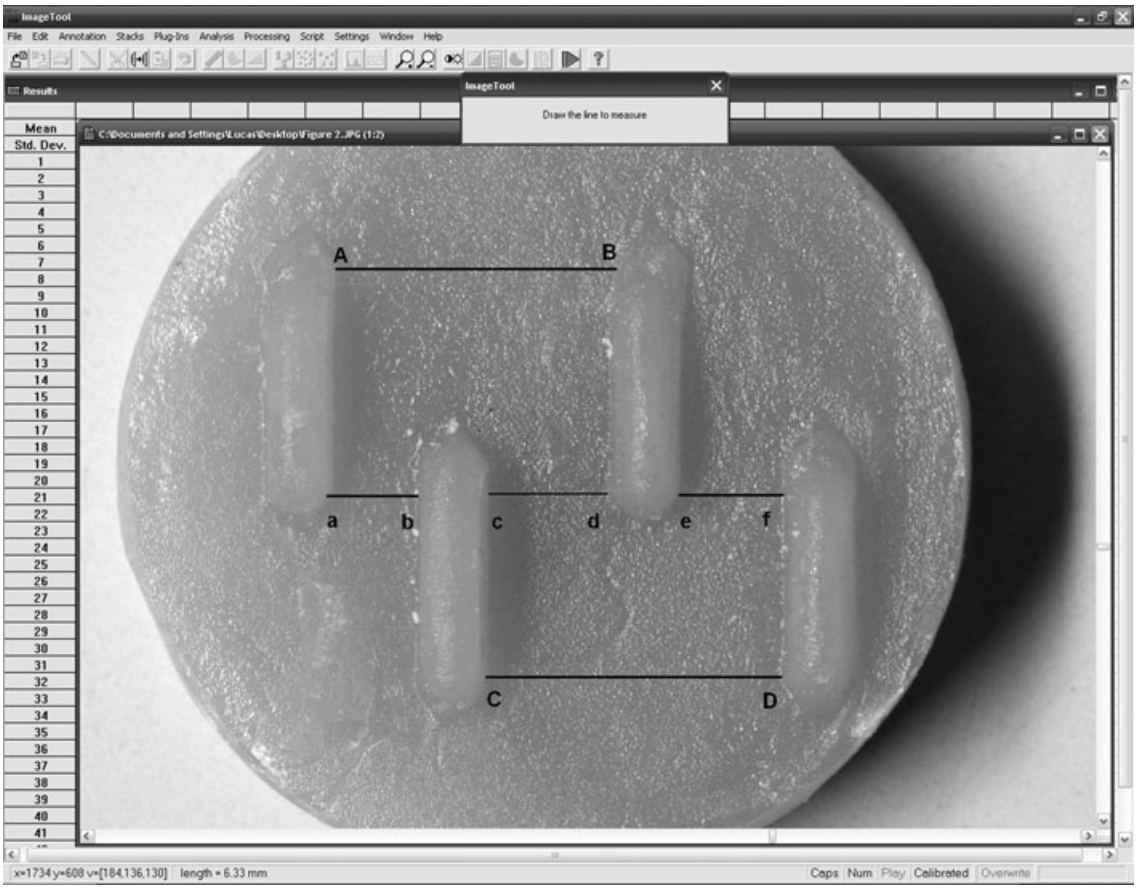

Figure 2 Major (A-B; C-D) and minor (a-b; c-d; e-f) axes used to measure the distance between the markings (mm) by Image Tool software.

Table 2 Artificial saliva composition

Components	Percentage
Potassium phosphate monobasic	0.036%
Potassium phosphate dibasic anhydrous	0.08%
Sorbitol	4.27%
Potassium chloride	0.063%
Magnesium chloride	0.012%
Calcium chloride	0.0072%
Sodium chloride	0.0863%
Sodium saccharin	0.03%
Preservative	0.83%
Natrosol 250 HHR	0.1%
Water	q.s.p.

both presented dimensional change after storage, with values of distance between axes similar statistically ($p > 0.05$). The difference of the distance between the axes, before and after storage, was calculated, and the highest values of dimensional change were found for the specimens of GVII (2.28 ± 0.47 and 1.32 ± 0.57) and GIII (2.08 ± 0.42 and 1.12 ± 0.56), similar statistically ($p > 0.05$) to each other, but different statistically from GI ($p < 0.05$), which presented the smallest average distance between both axes (1.37 ± 0.52 and 0.48 ± 0.40) (Table 3).

Discussion

Several studies have shown that resins are capable of absorbing water when immersed in liquid.[23,24] This absorption, which derives mainly from the polar properties of resin macromolecules through a diffusion process,[25] increases the capacity of the denture resin base to adapt and be retained on the edentulous ridge tissue.[26] The macromolecules of Polymethyl-methacrylate are gigantic and highly complex molecules with a heterogeneous conformation, having discontinuous empty spaces and unequal interstices, which also vary according to their composition.[27] One of the main properties of acrylic resins is related to the polar properties of polymers and to the physical presence of these spaces, or their capacity to absorb water when immersed in liquid environments.[28] The mechanism of liquid absorption originates from the diffusion of water molecules among polymeric macromolecules, as set forth by the laws of diffusion.[24,29] The time required for specimen saturation or drying is predictable[24] and may vary according to the acrylic resin processing method employed[30,31] and the composition of the resin storage fluid.[32] Acrylic resins stored in water increase in weight, but when placed in dry conditions, their weight decreases, and their dimensions alter.[24]

Clinically, the fit of a denture base is enhanced by the ability of the denture-bearing mucosa to adapt slightly to the denture base. Therefore it is suggested that although some dimensional changes were statistically significant, they were sufficiently small to be clinically relevant.[32] Anderson et al[1] demonstrated an increase in linear dimension of acrylic resin denture bases after 30 days in water immersion. Both injection and conventionally processed acrylic resins had expanded, but not sufficiently to compensate for polymerization shrinkage. Keenan et al[33] compared the same maxillary dentures and showed that after 28 days in water, all specimens showed expansion; however, the difference between the groups was not statistically significant or clinically relevant, as the amount of change was small.

It is known that acrylic resin suffers water sorption during polymerization due to the diffusion process.[34] The water molecules interfere with the interlocking of the polymeric chains and alter the physical characteristics of the resultant polymer, which could cause excessive dimensional change, thus affecting the long-term clinical success of the prostheses.[35]

Water absorbed by acrylic resin stays in gaps among the interpolymeric chains that form acrylic resin structure. The magnitude of these interpolymeric gaps determines the amount of water to be absorbed. Better polymerization of acrylic resin increases the crosslinking and reduces water sorption values.[30]

According to Ogawa and Hasewaga,[36] the increase of temperature and the pressured wet condition used in the acrylic resin thermally activated polymerization process produces a chemical reaction between monomer and polymer, producing a more complete polymerization, therefore, with few gaps, and consequently, less water sorption. The results of the present study agree, because the specimens of GI (thermally activated) had the smallest dimensional change, statistically different from GIII and GVII ($p < 0.05$). Furthermore, that difference could be explained by the AAA process to which GI was submitted. This suggests that AAA helped in the post-polymerization specimens of this group, and consequently, there was a greater conversion of the monomer and increase in crosslinking. These

Table 3 Average difference and standard deviation (SD) of the distance (mm) between major and minor axes of the studied groups before and after storage ($p < 0.05$)

Thermally		Chemically	
Major axis	Minor axis	Major axis	Minor axis
GI (1.37 ± 0.52)[a]	GI (0.48 ± 0.40)[a]	GV (1.65 ± 0.52)[ab]	GV (1.00 ± 0.18)[ab]
GII (1.63 ± 0.50)[a]	GII (0.69 ± 0.43)[a]	GVI (1.56 ± 0.58)[a]	GVI (0.61 ± 0.33)[a]
GIII (2.08 ± 0.42)[b]	GIII (1.12 ± 0.56)[b]	GVII (2.28 ± 0.47)[b]	GVII (1.32 ± 0.57)[b]
GIV (1.58 ± 0.45)[ab]	GIV (0.69 ± 0.39)[ab]	GVIII (1.82 ± 0.57)[a]	GVIII (0.64 ± 0.50)[a]
GIX (0.32 ± 0.15)[c]	GIX (0.12 ± 0.08)[c]	GX (0.37 ± 0.12)[c]	GX (0.11 ± 0.08)[c]

Different letters mean statistically significant difference.

data corroborate the study of Lee and Powers,[37] who affirmed that the high temperature of AAA causes an increase in the degree of polymerization of polymers. The results obtained under the conditions of this study support the hypothesis that dimensional stability could be affected by water storage; therefore, to store dentures in a dry environment would be better than in wet conditions, since dry storage produced the least dimensional change.

Conclusions

Within the limitations of this study, such as the software analysis and the artificial saliva composition, in comparison to the natural intraoral environment conditions, it could be concluded that:

(1) All acrylic resin specimens exhibited dimensional changes after processing, regardless of storage condition or exposure to an AAA process.
(2) Dry storage resulted in the least dimensional change in the acrylic resin specimens.
(3) The effect of water sorption on the acrylic resin specimen dimensional change was decreased by subjecting the specimens to an AAA process.

References

1. Anderson GC, Schulte JK, Arnold TG: Dimensional stability of injection and conventional processing of denture base acrylic resin. J Prosthet Dent 1988;60:394-398
2. Salim S, Sadamori S, Hamada T: The dimensional accuracy of rectangular acrylic resin specimens cured by three denture base processing methods. J Prosthet Dent 1992;67:879-881
3. Wong DMS, Cheng LYY, Chow TW, et al: Effect of processing method on the dimensional accuracy and water sorption of acrylic resin dentures. J Prosthet Dent 1999;81:300-304
4. Woelfel JB, Paffenbarger GC, Sweeney WT: Clinical evaluation of complete dentures made of 11 different types of denture base materials. J Am Dent Assoc 1965;70:1170-1188
5. Chen JC, Lacefield WR, Castleberry DJ: Effect of denture thickness and curing cycle on the dimensional stability of acrylic resin denture bases. Dent Mater 1988;4:20-24
6. Jackson AD, Grisius RJ, Fenster RK, et al: Dimensional accuracy of two denture base processing methods. Int J Prosthodont 1989;2:421-428
7. Compagnoni MA, Barbosa DB, de Souza RF, et al: The effect of polymerization cycles on porosity of microwave-processed denture base resin. J Prosthet Dent 2004;91:281-285
8. Consani RL, Domitti SS, Rizzatti Barbosa CM, et al: Effect of commercial acrylic resins on dimensional accuracy of the maxillary denture base. Braz Dent J 2002;13:57-60
9. Wilson J: The aetiology, diagnosis and management of denture stomatitis. Br Dent J 1998;185:380-384
10. Fenlon MR, Sherriff M, Walter JD: Factors associated with the presence of denture related stomatitis in complete denture wearers: a preliminary investigation. Eur J Prosthodont Restor Dent 1998;6:145-147
11. Arendorf TM, Walker DM: Denture stomatitis: a review. J Oral Rehabil 1987;14:217-227.
12. Radford DR, Challacombe SJ, Walter JD: Denture plaque and adherence of Candida albicans to denture-base materials in vivo and in vitro. Crit Rev Oral Biol Med 1999;10:99-116
13. Wolfaardt J, Cleaton-Jones P, Fatti P: The influence of processing variables on dimensional changes of heat-cured poly(methyl methacrylate). J Prosthet Dent 1986;55:518-525
14. Yeung KC, Chow TW, Clark RKF: Temperature and dimensional changes of two stage denture curing. J Dent 1995;23:245-253
15. Pow EHN, Chow TW, Clark RKF: Linear dimensional change of heat cured acrylic resin complete dentures after reline and rebase. J Prosthet Dent 1998;80:238-245
16. Polukoshko KM, Brudvik JS, Nicholls JI, et al: Evaluation of heat cured resin bases following addition of denture teeth using a second heat cure. J Prosthet Dent 1992;67:556-562
17. Lee YK, Powers JM: Combined effects of staining substances on resin composites before and after surface sealant application. J Mater Sci Mater Med 2007;18:685-691
18. Sarafianou A, Iosifidou S, Papadopoulos T, et al: Color stability and degree of cure of direct composite restoratives after accelerated aging. Oper Dent 2007;32:406-411
19. Schulze KO, Marshall SJ, Ganski SA, et al: Color stability and hardness in dental composites after accelerated aging. Dent Mater 2003;19:612-619
20. Pires-de-Souza FCP, Garcia LFR, Hamida HM, et al: Color stability of composites subjected to accelerated aging after curing using either a halogen or a light emitting diode source. Braz Dent J 2007;18:119-123
21. ASTM STANDARDS G154-00A: Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials. Annual Book of ASTM Standards, Vol 14 (ed 04). Philadelphia, ASTM, 2006, pp. 646-654
22. Douglas RD: Color stability of new-generation indirect resins for prosthodontic application. J Prosthet Dent 2000;83:166-170
23. Dogan A, Bek B, Çevik NN, et al: The effect of preparation conditions of acrylic denture base materials on the level of residual monomer, mechanical properties and water absorption. J Dent 1995;23:313-318
24. Abd Shukor SS, Juszczyk AS, Clark RKF, et al: The effect of cyclic drying on dimensional changes of acrylic resin maxillary complete dentures. J Oral Rehabil 2006;33:654-659
25. Arima T, Murata H, Hamada T: The effects of cross-linking agents on the water cure and solubility characteristics of denture base resin. J Oral Rehabil 1996;23:476-480
26. Skinner EW, Chung P: The effect of surface contact in the retention of dentures. J Prosth Dent 1952;1:229-235
27. Anusavice KJ: Chemistry of synthetic resins. In Anusavice KJ (ed): Phillip's Science of Dental Materials, Vol 1 (ed 11). Philadelphia, Saunders, 2003, pp. 211-235
28. Lai CP, Tsai MH, Chen M, et al: Morphology and properties of denture acrylic resins cured by microwave energy and conventional water bath. Dent Mater 2004;20:133-141
29. Miettinen VM, Vallittu PK, Docent DT: Water cure and solubility of glass fiber-reinforced denture poly methyl methacrylate resin. J Prosthet Dent 1997;77:531-537
30. Yannikakis S, Zissis A, Polyzois G, et al: Evaluation of porosity in microwaveprocessed acrylic resin using a photographic method. J Prosthet Dent 2002;6:613-619
31. Azzarri MJ, Cortizo MS, Alessandrini JL: Effect of the curing conditions on the properties of an acrylic denture base resin microwave-polymerised. J Dent 2003;31:463-468
32. All-Mulla MB, Murphy WM, Huggett RA, et al: Effect of water and artificial saliva on mechanical properties of some denture-base materials. Dent Mater 1989;5:399-402

33. Keenan PLJ, Radford DR, Clark RKF: Dimensional change in complete dentures fabricated by injection molding and microwave processing. J Prosthet Dent 2003;89: 37-44
34. Meloto CB, Silva-Concílio LR, Machado C, et al: Water sorption of heat-polymerized acrylic resins processed in mono and bimaxillary flasks. Braz Dent J 2006;17:122-125
35. Miéssi AC, Goiato MC, dos Santos DM, et al: Influence of storage period and effect of different brands of acrylic resin on the dimensional accuracy of the maxillary denture base. Braz Dent J 2008;19:204-208
36. Ogawa T, Hasegawa A: Effect of curing environment on mechanical properties and polymerizing behaviour of methyl-methacrylate autopolymerizing resin. J Oral Rehabil 2005;32:221-226
37. Lee YK, Powers JM: Color changes of resin composites in the reflectance and transmittance modes. Dent Mater 2007;23:259-264