Effect of Metallic Flask Closure and Investment Materials on the Stability of the Denture Base Resin

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ABSTRACT: This study evaluated the dimensional stability of the poly-methylmethacrylate (PMMA) denture bases under the effect of different metallic flask closure techniques (FCT) and investment materials (IM). Sixty stone cast maxillary-wax base plate sets were randomly assigned to six groups ($n = 10$) for the following treatments: 1 and 4—stone or silicone investments and flask closure with clamp; 2 and 5—stone or silicone investments and flask closure with RS system; 3 and 6—stone or silicone investments and flask closure with screws. PMMA denture bases were polymerized in a water bath at 74°C for 9 h. PMMA base-stone cast sets were sectioned at regions (R) of the canines, first molars, and posterior palatal zone. Gap discrepancies were measured at five points: right and left ridge crests, palatal midline, and right and left marginal limits of the flanges. An optical micrometer with accuracy of 0.0005 mm was used for measurement purposes. Data were submitted to ANOVA and Tukey's test ($\alpha = 0.05$). Silicone showed an adaptation mean (0.177 mm) significantly different when compared with stone (0.207 mm). The RS system presented a statistically different adaptation mean (0.166 mm) in relation to the traditional clamp (0.200 mm) and flask with screws (0.211 mm). Adaptation values for the regions of the canines (0.141 mm), first molars (0.185 mm), and posterior palatal (0.250 mm) were statistically different. For all flask closure techniques, better adaptation was shown with the RS system and silicone investment. © 2010 Wiley Periodicals, Inc. J Appl Polym Sci 116: 1467–1474, 2010

Key words: dental polymers; resins; silicones; monomers

INTRODUCTION

Some *in vitro* studies have shown that the dimensional stability of PMMA dental polymer is an important factor to be considered during complete denture processing.[1–3]

Denture base adaptation to the stone cast is not satisfactory, mainly in the midline regions of the central portion of the posterior border,[4–9] and gap discrepancies in the adaptation are not easily corrected after complete denture processing.[10] Denture base accuracy is also influenced by the types of PMMA polymers,[5,11,12] depends upon the palate vault shape,[13] stresses released,[14–16] processing techniques of the dentures,[17–24] and it is considered a critical and unresolved problem.[25–31]

Thermal polymerization shrinkage by flask cooling and the distortion resulting from the stresses released after denture base resin removal from the stone cast are conjugated events, which decrease the accuracy of the complete denture adaptation and stability in use.[32]

An interesting point in the denture base resin procedure is that the flask should be closed with reasonable speed and under considerable pressure during definitive closure so as to confine the polymer dough in the mold with no excess.[33] To avoid denture base resin distortion, metal-to-metal contact is necessary between the halves of the flask after definitive closure. Furthermore, the use of a spring clamp may allow the halves of the flask to open too much during polymerization, resulting in a flash.[34]

An increase in the thickness of the denture base resin at the palatal region can be attributed to the two halves of the flask, which are difficult to completely close after separation, especially if the flask has been severely scratched.[35]

Traditional pressure techniques do not maintain the metal-to-metal contact before the flask is placed in the traditional spring clamp.[34] This condition probably causes a premature release of the residual stresses from the PMMA dough before the flask

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closure by the flask carrier. To maintain constant metal-to-metal contact at the flask halves before press releasing, a flask closure system showed decrease in the dimensional changes in the PMMA maxillary denture bases when compared with the traditional flask clamp.[26]

Another significant factor to be considered is the type of material used to include the base plate. The investment procedure is carried out, usually, with plaster, which complicates the deflasking of the prosthesis. Investment with silicone has been also proposed with the aim of easing finishing, since during the traditional use of plaster, residues remain joined to the denture base resin and/or to the interproximal space of the artificial teeth.[36–38]

Although this laboratorial advantage may be considered important, conflicting results are showed in the literature. Vertical occlusal changes that occur in complete dentures made with PMMA polymer are similar to those achieved with the stone or silicone investment procedures.[37] The maintenance of the vertical occlusal dimension of the prosthesis and teeth displacement are also not influenced by stone or silicone investments.[39] Occlusal accuracy obtained with a layered silicone rubber mold was markedly superior to that of the usual method of processing in split molds made of gypsum products.[36]

Despite the claimed better dimensional stability of silicone when compared with stone, the combination of investment material and water storage has been shown not alter the distance among teeth, with the exception of the premolar-to-premolar distance after water storage for 90 days.[40] Conversely, the investment procedure with a silicone layer recovered with stone showed general tendency for reduction in the distance between first molars and between first molars and central incisors.[38] It was also showed that the greater shrinkage in the palatal area of the denture base resin does not occur when silicone liner was used.[41]

The purpose of this study was to investigate the dimensional stability of maxillary denture base resin processed by different flask closure methods (traditional clamp, RS system, and flask with screws) and investment materials (stone or silicone). The hypothesis of this *in vitro* study is that different flask closure methods and investment materials could influence the adaptation accuracy of the denture base resin to the stone cast.

MATERIALS AND METHODS

A silicone mold (Elite Double; Zhermack, Rovigo, Italy) simulating an edentulous maxillary arch with no irregularities in the alveolar ridge walls was used. Sixty stone casts were poured in Type III dental stone (Herodent Soli-Rock; Vigodent, RJ, Brazil). An uniform wax base plate with a thickness of 2.0 mm, verified with a thickness measuring device (Golgran; Golgran Dental Products, SP, Brazil), was made on each stone cast by the same technician.

The cast-wax base plate sets were numbered from 1 to 60, and randomly assigned into the groups (n = 10): 1—stone investment and flask closure with traditional clamp; 2—stone investment and flask closure with RS system; 3—stone investment and flask closure with screws; 4—silicone investment and flask closure with traditional clamp; 5—silicone investment and flask closure with RS system; 6—silicone investment and flask closure with screws.

Stone cast-wax base plate sets of the Groups 1 and 2 were invested in the lower part of traditional brass flasks (Safrany; Safrany Dental Metallurgy, SP, Brazil) with Type II dental plaster (Pasom; Pasom Manufacturing and Trade, Sao Paulo, SP, Brazil). Using the same pour investment conditions, the casts of the Group 3 were invested in the lower part of an experimental brass flask, in which the assemblies were fixed with two screws. Petroleum jelly was used as a separating medium of the plaster. Type III dental stone (Herodent Soli-Rock) was used to invest the upper portion of the flask of the Groups 1, 2, and 3.

Stone cast-wax base plate set inclusions for silicone investment (Groups 4, 5, and 6) were made in the same conditions used for the stone investment. Afterward, the wax base plates were recovered with a layer of laboratory silicone (Zetalabor; Zhermack) with a 3 mm thickness. Type III dental stone (Herodent Soli-Rock) was used to include the upper portion of the flasks.

After the investing material had set, the wax was removed from the cast and the stone cleaned with a solution of hot water and liquid detergent (Ype; Amparo Chemical Products, SP, Brazil). One coat of sodium alginate (Isolak; Classico Dental Products, SP, Brazil) was used as a separating medium.

The PMMA polymer (Batch No. 009–04, Classico; Classico Dental Products, Sao Paulo, SP, Brazil) was prepared for each flask packing with a monomer : polymer ratio of 35.5 g powder to 15 mL liquid, according to the manufacturer's instructions.

The prepared PMMA dough was packed in the dough-like stage according to the group assignments. A polyethylene sheet was used as a separating medium during the initial flask packing under a load of 850 kgf in a hydraulic press (Linea H; Linea, SP, Brazil). After the flask opening, the polyethylene sheet was removed and the PMMA flash removed.

Flasks for the conventional closure technique (Groups 1 and 4) were placed in a traditional clamp [Fig. 1(b)] after final pressing under a load of 1250 kgf for 5 min.[27] In the modified techniques (Groups 2, 3, 5, and 6), the same trial pack at definitive

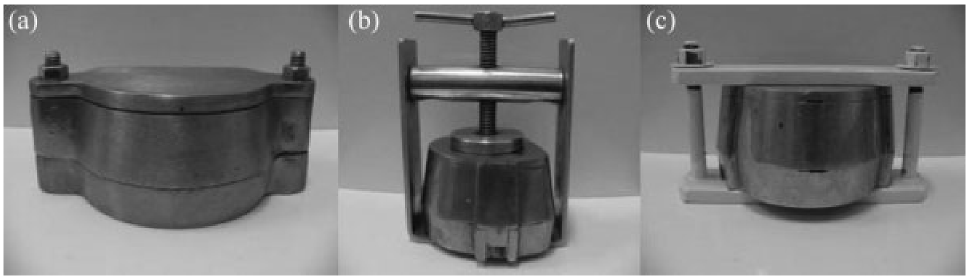

Figure 1 Flask closure types: (a) screws, (b) traditional metallic clamp, (c) RS.

closure was used. The flasks of the Groups 2 and 5 [Fig. 1(c)] were positioned between the two plates of the RS system.[26] After hydraulic flask pressure, the screw-nuts were strongly tightened to the screws until just one stop before press releasing. The experimental flask of the Groups 3 and 6 [Fig. 1(a)] was developed by the authors (Brazilian patent MU-8.200.888–4) and is similar in shape and size to a standard brass flask, with the exception that it has two lateral extensions to fit the halves of the flask with locknuts tightened on the screws before press releasing.

Flasks were immersed in water at room temperature (25°C ± 2°C) and the PMMA polymer cured in the polymerization unit (Thermotron; Piracicaba, SP, Brazil) at 74°C for 9 h, in accordance with the manufacturer's instructions.

After the flasks were allowed to bench cool for 3 h,[42] the denture base resin specimens were carefully deflasked without to damage the stone casts. Afterward, the denture base was finished and returned to the corresponding stone cast. To avoid displacement during the sawing procedure, the denture base was fixed to the stone cast with an instantaneous adhesive (Super Bonder; Loctite, Cotia, SP, Brazil). The adhesive was placed on the ridge crest of the stone cast, and the denture base was submitted to a load of 1 kgf for 1 min.

A pattern denture was used to determine the exact areas in the sawing device where the stone cast-denture base resin sets should be sectioned. After the zone cut determination, the pattern denture was removed and each stone cast-denture base resin set was positioned in the sawing device to make the standardized cuts using a manual saw. Denture base resin-stone cast sets were transversally sectioned at corresponding regions of the canines, first molars, and posterior palate. The sawing movement was very slow to avoid heat generation and consequent dimensional change in the denture base resin.[26]

The gap between denture base resin and stone cast was measured in five reference points along the three sections, (a) canines, (b) first molars, and (c) posterior palate (Fig. 2), corresponding to the right and left ridge crests, the midline, and the right and left marginal limits of the flanges (Fig. 3). An optical micrometer (Olympus Optical; Tokyo, Japan) with tolerance of 0.0005 mm was used for measurement purposes.

Collected data were submitted to ANOVA in three-way analysis, and the factors studied were investment material (IM), flask closure technique (FCT), and Region (R). Their interactions were also verified. The means were compared by Tukey's test at a significance level of $\alpha = 0.05$.

RESULTS

Three-way ANOVA revealed significant difference in the IM ($P < 0.00001$), FCT ($P < 0.00001$), and R ($P < 0.00001$). Interactions between IM and FCT ($P < 0.00020$); IM and R ($P < 0.00040$), FCT and R ($P < 0.01485$) are also statistically significant. There was no significant difference in the IM-FCT-R interaction ($P > 0.56257$).

Table I shows that the mean value for denture base resin adaptation with silicone investment was significantly lower ($P < 0.05$) than that related with stone investment, regardless of other factors. The mean adaptation of the denture base resin was statistically different ($P < 0.05$) when the FCT were compared.

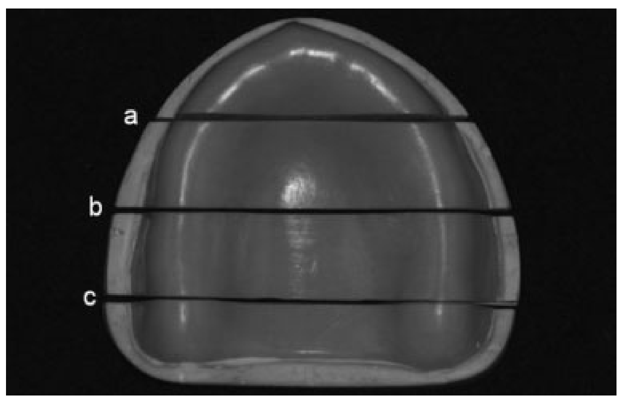

Figure 2 Sections for measurement: (a) canines, (b) first molars, and (c) posterior palate.

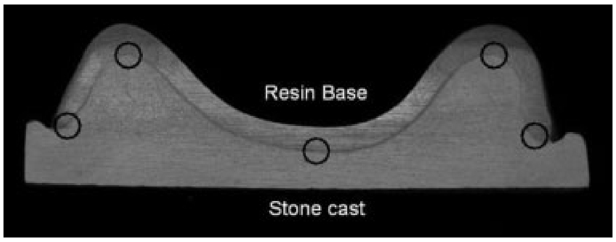

Figure 3 Reference points for adaptation measurements in each section.

The best denture base resin adaptation ($P < 0.05$) was achieved with the RS system and the worst with the flask with screws, with the traditional clamp presenting an intermediate value (Table II).

The mean adaptation of the denture base resin was statistically different ($P < 0.05$) when the R factor was compared. The best denture base resin adaptation was shown in the canines region and the worst in the posterior palatine, with the first molars region giving an intermediate value (Table III).

Table IV shows that for all FCT there was statistically better adaptation ($P < 0.05$) when silicone was compared with stone. For the silicone investment, statistical difference ($P < 0.05$) occurred when the RS system was compared with the traditional clamp and flask with screws, both with no significant difference ($P > 0.05$).

In all R, statistically better adaptation ($P < 0.05$) was observed when silicone was compared with stone (Table V). Significant differences ($P < 0.05$) were seen in the denture base resin adaptation values in the comparison among R for both IM. The best denture base resin adaptation was seen in the canines region and the worst in the posterior palatine, with the first molars region giving an intermediate value.

Table VI shows that in the canines and first molars regions, there were no statistically significant difference ($P > 0.05$) between the denture base resin adaptation values for the traditional clamp and flask with screws; both were higher when compared with RS system ($P < 0.05$). For the posterior palatal region, the FCT provided statistically significant differences ($P < 0.05$). When the values for denture base resin adaptation were compared for each FCT, there was a significant difference ($P < 0.05$) among R, with the best denture base resin adaptation for the canines and the worst for the posterior palatal; the first molars gave intermediate values.

TABLE I
Mean Denture Base Adaptation (mm) and Standard Deviation in Relation to IM, Independent of Other Factors

Investment material (IM)	Mean PMMA base adaptation
Stone	0.207 (0.06) a
Silicone	0.177 (0.04) b

Means followed by different lower case letters are significantly different by Tukey's test at the 95% confidence level.

TABLE II
Mean Denture Base Adaptation (mm) and Standard Deviation in Relation to FCT, Independently of Other Factors

Flask closure technique (FCT)	Mean PMMA base adaptation
Screws	0.211 (0.06) a
Clamp	0.200 (0.05) b
RS system	0.166 (0.04) c

Means followed by different lower case letters are significantly different by Tukey's test at the 95% confidence level.

DISCUSSION

The purpose of this investigation was to compare the influence of investment materials and flask closure methods on the maxillary denture base resin adaptation. In this *in vitro* study, the research hypothesis that investment materials and flask closure methods could influence the adaptation of the denture base resin on the stone cast was accepted.

When the complete denture retention is considered, discrepancies in the denture base resin adaptation due to PMMA curing procedures are not easily corrected after processing,[10] mainly in the posterior palatal zone.[5–9] Polymerization shrinkage, thermal contraction due to the flask cooling, and stresses released after complete denture removal from the stone cast are also combinations responsible for dimensional changes and distortion of the denture base resin, which decrease the adaptation accuracy.[32]

Table I shows better denture base resin adaptation to the stone cast when silicone was used. Silicone investment is also recommended to facilitate

TABLE III
Mean Denture Base Adaptation (mm) and Standard Deviation in Relation to R, Independent of Other Factors

Region (R)	Mean PMMA base adaptation
Posterior palate	0.250 (0.04) a
First molar	0.185 (0.03) b
Canine	0.141 (0.02) c

Means followed by different lower case letters are significantly different by Tukey's test at the 95% confidence level.

TABLE IV
Mean Denture Base Adaptation (mm) and Standard Deviation in Relation to IM and FCT Interaction

	Flask closure technique (FCT)		
Investment material (IM)	Clamp	RS system	Screws
Stone	0.212 (0.05) aB	0.173 (0.05) aC	0.237 (0.07) aA
Silicone	0.188 (0.04) bA	0.159 (0.03) bB	0.185 (0.04) bA

Means followed by different lower case letters in each column and upper case letters in each row are significantly different by Tukey's test at the 95% confidence level.

deflasking and finishing, without the presence of stone adhered to complete denture.[38] However, another important advantage of this investment material is the inclusion technique, when complete denture flasked with stone covered by a silicone liner showed better palatal adaptation than when included with stone alone.[41]

Better linear dimensional stability of silicone when compared with stone[40] appears to be the factor responsible for the improved denture base resin adaptation in this study. Other study has reported no statistically significant differences in denture base resin accuracy, when silicone and stone investment materials were compared.[37]

It may be assumed that the properties of the silicone used in this study are different and, probably, better than those presented by the silicones investigated by those authors,[36–39] increasing the difference between results for silicone and stone used in this study. Stone also demonstrates dimensional changes promoted by the water absorption,[3] a factor that could contribute to this difference in the behavior of the investment materials. These contrasting findings show the complexity of the factors involved in the comparison of data obtained in similar studies.

Furthermore, the polymerization shrinkage may be partially compensated by the thermal expansion of the PMMA polymer during the curing and, later, this expansion may be constricted by the flask.[2] This constriction, however, would not be very evident in the silicone investment due to its small modulus of elasticity. In other words, PMMA dough accommodates better on an elastic investment than on a rigid material.

Under similar analysis conditions, the denture base resin processed with RS system showed a smaller adaptation discrepancy that was statistically different when compared with the flask with screws and the traditional clamp techniques (Table II). It is claimed that the RS system technique decreases the discrepancy between denture base resin and stone cast.[8,26,27] In this study, although the RS system had reduced the discrepancy of the denture base resin when compared with the traditional clamp and the flask with screws, it was not possible to completely eliminate the dimensional change of the PMMA polymer occurred during the denture procedure.

Despite the smaller discrepancy with the RS system, the denture base resin adaptation remains an inherent factor of the procedure, and results from the combination among changes occurred in the polymerization, thermal shrinkage by flask cooling, and stresses released during deflasking.[2,13,14,28–30,35]

When the region factor was analyzed, there were statistically significant differences among denture base resin adaptation means (Table III). A lower value was observed for the canines region and a higher value for the posterior palatal, with the first molars region demonstrating an intermediate value.

Dimensional change due to denture base resin procedure is considered complex, where the multiple factors involved remain similar to the study previously related[15] and poorly defined. The complexity of the polymerization procedure begins in the monomer chemical reaction that forms large polymer molecules and the polymerization shrinkage has considerable magnitude.[3]

The PMMA heated mass remains softened due to the thermal polymerization reaction, which allows the slackness of the inner stress resultant from the shrinkage.[16] The PMMA linear shrinkage exerts an

TABLE V
Mean Denture Base Adaptation (mm) and Standard Deviation in Relation to IM and R Interaction

	Region (R)		
Investment material (IM)	Canines	First molars	Posterior palatine
Stone	0.149 (0.02) aC	0.197 (0.03) aB	0.276 (0.05) aA
Silicone	0.134 (0.01) bC	0.173 (0.02) bB	0.225 (0.02) bA

Means followed by different lower case letters in each column and upper case letters in each row are significantly different by Tukey's test at the 95% confidence level.

TABLE VI
Mean Denture Base Adaptation (mm) and Standard Deviation in Relation to FCT and R Interaction

	Region (R)		
Flask closure technique (FCT)	Canines	First molars	Posterior palatine
Clamp	0.152 (0.05) aC	0.189 (0.05) aB	0.258 (0.07) bA
RS system	0.122 (0.04) bC	0.162 (0.03) bB	0.214 (0.04) cA
Screws	0.150 (0.04) aC	0.205 (0.04) aB	0.278 (0.04) aA

Means followed by different lower case letters in each column and upper case letters in each row are significantly different by Tukey's test at the 95% confidence level.

effect on denture base resin adaptation, which leads to greater linear shrinkage and greater discrepancy. At the beginning of the cooling stage, the PMMA remains softened and the flask pressure promotes contraction at a similar speed to the stone shrinkage. When the cooling proceeds, the softened PMMA falls to the temperature of vitreous transition, passing from the softened stage or plastic to vitreous stiffness, shrinking at a different speed from the stone (thermal contraction). The attrition between the stone and softened PMMA can inhibit the polymerization shrinkage, establishing tension stress by thermal shrinkage. Consequently, the release of this inner stress causes dimensional changes.[3]

The denture base resin contraction in this study was more evident at the posterior palatal region (Table III), corroborating with classic results shown in the literature,[6,13,25,28,31,32] and other more recent works.[5,7–9,17,26,27]

Several studies have shown that the denture base resin adaptation to the stone cast remains unsatisfactory due to the influence of many factors, such as base thickness,[18,19] palate vault shape,[13] different regions of the denture base,[24] stone cast position inside the flask,[1] and packing[20]; however, no interaction of the polymerization cycles has been demonstrated.[21] These findings confirm the complexity of the variables that are associated with the methods for complete denture procedure.

Dimensional changes from −0.05 to +0.2 mm did not affect the performance of the complete denture in use.[22] Inaccuracies in the posterior palatal region were relativity constant (0.22 to 0.27 mm), and appear to have little clinical significance as they do not exceed the tolerance of the oral mucosa resilience.[23]

Independently of the denture base resin adaptation level, retention is also based on the combination of muscular forces exerted by the cheek, tongue, and lips and physical forces acting among the supporting tissues, the complete denture, and the viscosity of the saliva film.[43]

Another interesting factor that could support the complexity of the complete denture procedure would be the statistically significant difference shown in the adaptation level among regions (Table III). These findings demonstrate that the combination among polymerization shrinkage, flask cooling, and stress released by deflasking are factors responsible for these discrepancies.

The IM and FCT combination (Table IV) did not alter the pattern of the results shown in Table I. However, these results demonstrate a significant influence on the dimensional instability of the stone during the procedure when compared with silicone. According to a previous study,[44] during cooling period after polymerization, the denture base resin is restricted from contracting normally in all directions by the shape of the stone cast. This fact seems to explain the effect of stone in promoting different changes during the PMMA denture procedure.

In the silicone inclusion, statistical difference occurred between the RS system and the traditional clamp and flask with screws methods. It is possible that the silicone elasticity was responsible for the better results shown by the RS system. This finding was surprising because the flask closure for the RS system and flask with screws methods is similar, since the flask closure occurs before the flask removal from the hydraulic press. However, other studies have also identified better denture base resin adaptation when the RS system was used.[8,9,26] Thus, this finding requires future studies for clarification.

Table V shows that the best denture base resin adaptation was achieved with silicone, confirming the superiority of this material in this study. For both investment methods, statistically significant difference was observed in the denture base resin adaptation among regions, with a lower value for the canines region and a higher value seen for the posterior palatal. This interaction did not alter the pattern of adaptation verified in previous studies,[6,7,10–13,17,26] whose results were similar to the obtained in this current investigation.

There was statistically significant difference between the canines and first molars regions when the traditional clamp and flask with screws methods were compared with the RS system (Table VI). As discussed, this result was surprising because the flask closure method for the two systems is similar, a finding that demonstrates the necessity of future studies.

In the posterior palatal region, the denture base resin adaptation was statistically different among flask closure techniques, showing the complexity of the other factors involved in the procedure; however were not analyzed in this study, such as the palate vault shape[6,13] and PMMA polymer commercial types.[5]

FCT and R interaction, and comparison among R for each technique (Table VI) did not alter the pattern of denture base resin adaptation as presented in the literature, where studies show that best denture base resin adaptation occurs in the canines region and the worst in the posterior palatal region.[6,7,10,13,17,26]

The improvement in adaptation, shown by the combination of silicone and the RS system, permits better seating of the complete denture, independently of whether the oral tissue displacement provides (or not) conditions to compensate the inaccuracy of the denture base. Clinically speaking, better base stability means increased chewing efficiency and comfort for the patient when the denture is in use under masticatory loads.

According to patient reactions, dimensional changes not exceeding 0.2 mm did not significantly affect the serviceability of complete dentures.[22] Denture base inaccuracy obtained with the silicone investment and RS system association in this study was similar to that reported value.[22]

The use of silicone in the complete denture procedure could increase the cost of the prosthesis in some dental laboratories; however, the cost is compensated by better adaptation and stability of the denture, increasing the comfort for the patient. Methods to improve the denture accuracy and consequent chewing conditions should be recognized as an effort to increase the comfort of the patient.

This study shows the importance and complexity of the factors involved in complete denture procedure alone or in association. Dimensional changes of the denture base resin remain an objective for future studies and classic concepts claimed by earlier authors need to be ratified or better understood. For this reason, the effect of alternative polymerization cycles on the complete denture adaptation, involving the use of silicone, and clinical studies should be conducted to confirm these findings.

CONCLUSIONS

Within the limitations of this *in vitro* study, the following conclusions can be drawn:

1. Fewer dimensional changes were observed in the denture base resins processed with the RS system and silicone investment association. The best adaptation was observed for the canines region and the worst for the posterior palatal region.
2. FCT and IM should be considered when the complete dentures are realized.

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