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Effect of Monomer Content in the Monomer-Polymer Ratio on Complete Denture Teeth Displacement

Michelle Cristina LOPES[1]
Rafael Leonardo Xediek CONSANI[2]
Marcelo Ferraz MESQUITA[2]
Mário Alexandre Coelho SINHORETI[3]
Simonides CONSANI[3]

[1]*Piracicaba Dental School, UNICAMP - University of Campinas, Piracicaba, SP, Brazil*
[2]*Department of Prosthodontics and Periodontics, Piracicaba Dental School, UNICAMP - University of Campinas, Piracicaba, SP, Brazil*
[3]*Department of Restorative Dentistry, Piracicaba Dental School, UNICAMP - University of Campinas, Piracicaba, SP, Brazil*

The purpose of the study was to verify the linear displacement of teeth in maxillary complete dentures influenced by different monomer-polymer ratios - according to the manufacturer's instructions, with 25% excess or 25% less monomer content - in the conventional and microwaved polymerization techniques. Wax base plates and wax planes were made on edentulous maxillary stone casts according to traditional method. The set was assembled in semi-adjustable articulator with a lower toothed stone cast as guide to mounting of the maxillary artificial teeth. Impressions were taken from this tooth arrangement with silicone and the mold was used to standardize the mounting of the teeth of all dentures. Referential points were made on the artificial teeth for linear measurements with optical microscope before processing of the dentures and after deflasking. Denture bases were conventionally packed with acrylic resin according to the monomer-polymer ratio protocol. Tooth displacement data were submitted to ANOVA and Tukey test (α=0.05). There were no statistically significant differences ($p>0.05$) between the group with monomer content recommended by the manufacturer and groups with 25% more and 25% less monomer, in both conventional and microwaved polymerizations. Excess or less monomer in the monomer-polymer ratio and polymerization types did not change the linear distance between teeth.

Key Words: teeth displacement, monomer-polymer ratio, resin types, complete denture.

INTRODUCTION

The dental market offers several materials that can be applied in restorative procedures; however, the acrylic resin is still the only material used in the processing of complete dentures. This material shows several advantages, such as ease of processing, low cost, stable dimensional behavior in oral environment, adequate resistance against masticatory efforts, durability, solubility and negligible oral fluids sorption.

In addition to these advantages, it also provides satisfactory aesthetic characteristics, color stability and possibility of pigmentation and characterization. However, some disadvantages are present, namely polymerization contraction, distortion, and dimensional accuracy of the denture bases influenced by the commercial types of acrylic resins (1).

Some changes in the clinical performance of dentures may occur due to these negative factors previously mentioned, as modification in the positioning of artificial teeth during and/or after the resin polymerization, changing the relationship established in the wax planes and causing alterations in the vertical dimension of occlusion made before denture processing (2,3). These changes commonly occur during fabrication and after deflasking of the denture. However, when these changes are small they can be partially be compensated with clinical occlusal adjustment (4).

Correspondence: Prof. Dr. Rafael Leonardo Xediek Consani, Faculdade de Odontologia de Piracicaba, UNICAMP, Avenida Limeira, 901, 13414-903 Piracicaba, SP, Brasil. Tel: +55-19-2106-5296. Fax: +55-19-2106-5296. e-mail: rconsani@fop.unicamp.br

The position of the teeth can also be changed during the plaster set expansion used in the inclusion of the denture. Tooth displacement could be decreased because the plaster set expansion could compensate partially for the change caused by the polymerization contraction of the acrylic resin (5).

Another factor that can cause dimensional change in the acrylic resin is the monomer-polymer ratio. Proportions with higher polymer content can promote a dry mixture due to lack of monomer, resulting in a material mass with disabilities to convert monomer into polymer. Conversely, the excess content of monomer may produce a higher contraction due to excessive polymerization (6), and consequently loss of retention quality and denture stability in oral use.

Considering the possible dimensional changes caused by differences in the monomer-polymer ratio recommended by the manufacturer, the purpose of this study was to verify whether excessive or less monomer could influence on the linear displacement of teeth in complete dentures processed by the conventional and microwave energy techniques. The tested hypothesis is that different monomer content in the monomer-polymer ratio may influence the linear displacement of teeth in maxillary complete dentures.

MATERIAL AND METHODS

A conventional heat-polymerized acrylic resin (Vipi-Cril; VIPI Dental Products Co., Pirassununga, SP, Brazil; batches 86715 powder and 70942 liquid), a microwave-activated acrylic resin (Vipi-Wave; VIPI Dental Products Co., batches 77728 powder and 70945 liquid) and artificial teeth (Vip-Dent Plus; VIPI Dental Products Co., batch 9300/6792).

Thirty casts (n=10) were made with type III dental stone (Herodent; Vigodent, Rio de Janeiro, RJ, Brazil), dispensed and mixed according to the manufacturer's instructions (100 g of powder to 30 mL of water), from a silicon mold (Elite Double; Zhermack, Rovigo, Italy) representing an edentulous maxillary arch with normal edge, with no retentions or acute irregularities.

Wax base plates were prepared with thickness of 2.5 mm (7) using two #7 wax sheets (Epoxiglass Chemical Industry, Diadema, SP, Brazil) adapted to the stone cast. Afterwards, a wax plane with 10 mm of height in the posterior region and 20 mm in anterior region was fixed on the wax base plate.

The stone cast-wax base plate set was fixed with type II dental plaster (Passom Dental Products, São Paulo, SP, Brazil) in a semi-adjustable articulator (Bio-Art Dental Equipments, São Carlos, SP, Brazil), adjusting the intercondylar distance at M, the Bennet angle at 15 degrees and the condylar guidance at 30 degrees. A lower type IV stone cast (Herostone; Vigodent) with teeth was related to the wax plane of the maxillary denture and fixed with type II dental plaster (Passom Dental Products) on the articulator, setting the position of the incisal pin at zero and touching the incisal table.

Mounting of artificial teeth was performed starting by the central incisor, lateral incisor and canine of the right side. The same sequence was followed on the left side. The posterior teeth were mounted starting by the first premolar to the second molar of the right side and, afterward, the fitting was performed on the left side, in the same way.

After the tooth mounting, the cast was removed from the articulator and molded with laboratory silicone (Zetalabor; Zhermack) and the resulting matrix was used to standardize tooth mounting of the subsequent dentures. The artificial teeth were placed in the silicone matrix and a liquid wax (Epoxiglass Chemical Industry) was poured until filling the matrix. The stone cast was adapted in the silicone matrix and kept in position until the complete cooling of the wax at room temperature. Afterward, the stone cast-teeth set was carefully removed from the silicone matrix.

In order to measure the linear distances resulting from the possible displacement of the teeth, reference metallic pins were fixed in the median region of the incisal border of the central incisors, buccal cusp of the first premolar and distobuccal cusp of the second molars. Small holes were performed with #½ round bur (Maillefer, Petrópolis, RJ, Brazil) for fixation of the metallic pins with instantaneous adhesive (Super Bonder; Henkel Loctite, Itapevi, SP, Brazil).

Before denture processing, the distances between teeth were performed to check the standardization of assembly of the teeth. Measurements were taken at linear transverse distances between: central incisors, first pre-molars and second molars, and anteroposterior distances between the right central incisor and the right molar and the left central incisor and the left molar. For this purpose, a STM linear comparator microscope (Olympus Optical Co., Tokyo, Japan) with accuracy of 0.0005 mm was used.

The stone casts were coated with petroleum jelly and included in the lower part of traditional metallic

flasks (DCL Dental Products, Campinas, SP, Brazil) or plastic flasks (VIPI Dental Products Co.). The flasks were isolated and the casts fixed in the lower part with type II dental plaster (Passom Dental Products), dispensed and mixed in accordance to the manufacturer's recommendations.

After 1 h, the surface of the plaster was coated with petroleum jelly and the denture was covered with a 3-mm-thick silicone layer (Zetalabor; Zhermack). Complete inclusion was done with type III dental stone (Herodent; Vigodent) dispensed and mixed in accordance to the manufacturer's recommendations. The flasks were pressed in hydraulic press (VH Equipment, Araraquara, SP, Brazil) for 1 h (8).

After removal of the wax base plate, the flasks were placed in boiling water for 5 min to soft the wax. Teeth and plaster were washed with a solution of hot water and liquid detergent (Ype; Amparo Chemist Co, Amparo, SP, Brazil) to remove wax traces. In order to increase the mechanical and chemical bond between teeth and acrylic resin base (9), the ridge lap surface of the tooth was grooved with a #8 round bur (Maillefer).

A sodium alginate layer (VIPI Dental Products Co.) was used as insulation medium for the plaster before the acrylic resin pressing, performed according to following experimental groups: Groups VCM and VWM: the dentures were made with Vipi-Cril and Vipi-Wave (VIPI Dental Products Co.) acrylic resins prepared in accordance to manufacturer's recommendation (14 g polymer to 6.5 mL monomer, in volume) and packed in dough like stage. In the initial flask closure a plastic sheet was used as an insulation medium between gypsum and acrylic resin. The flask was closed using a hydraulic press (VH Equipment) under a load of 850 kgf (VCM) or 800 kgf (VWM) for flash of the resin. After plastic sheet removal and resin mass excess trimmed, the final closure was made with loads of 1,250 kgf (VCM) and 1,000 kgf (VWM); Groups VCE and VWE: the same procedures were performed as described for the VCM and VWM, except that the content of monomer in the monomer-polymer ratio was 25% in excess than the manufacturer's recommendation; and Groups VCL and VWL: the same procedures were performed as described for the VCM and VWM, except that the content of monomer in the monomer-polymer ratio was 25% less than the manufacturer's recommendation.

After packing, the metallic flasks (groups VCM, VCE and VCL) were placed in traditional clamps and immersed in water in an automatic heat polymerizing unit (Termotron Dental Products, Piracicaba, SP, Brazil) for the polymerization of the acrylic resin in water at 74°C for 9 h. The plastic flasks (groups VWM, VWE and VWL) were pressed in a hydraulic press, closed with screws and the acrylic resin polymerized according to manufacturer's recommendation (initial stage: 20 min at medium-low potency, and b) final stage: 5 min at medium potency) in a domestic microwave oven (Panasonic, Manaus, AM, Brazil) with potency of 900 W.

After polymerization, the flasks were cooled at room temperature, the dentures deflasked, small excess of resin was removed with a maxi-cut bur (Maillefer) and finishing was done with sandpapers. Afterwards, the linear distances between teeth were measured according to previously described for measurements before denture procedure.

Data obtained in the transverse and anteroposterior distances were submitted to two-way ANOVA and Tukey's test at 5% level of significance, considering the factors *resin* and *monomer-polymer ratio* and their interactions.

RESULTS

Table 1 shows the means of the distance between the teeth for the conventional polymerization. There was no statistically significant difference ($p>0.05$) in the values of the I-I, PM-PM, M-M, RI-RM and LI-LM distances when the manufacturer's ratio, 25% excess and 25% less monomer content were compared.

Results of the distance between the teeth for the microwaved resin are shown in Table 2. There was no statistically significant difference ($p>0.05$) in the values of the I-I, PM-PM, M-M, RI-RM and LI-LM distances comparing manufacturer's ratio, 25% excess and 25% less monomer content.

Table 3 shows the results of the distance between the teeth for both conventional and microwave activations, considering the manufacturer's ratio. There was no statistically significant difference ($p>0.05$) among the I-I, PM-PM, M-M, RI-RM and LI-LM distances when the manufacturer's ratio, 25% excess and 25% less monomer content were compared.

Means of the distance between teeth for the conventional and microwave activations, considering the proportion with 25% excess of monomer are shown in Table 4. There was no statistically significant difference ($p>0.05$) among the I-I, PM-PM, M-M, RI-RM and LI-LM distances.

Table 5 shows the means of the distance between teeth for the conventional and microwave activations, for the proportion with 25% less of monomer. There was no statistically significant difference ($p>0.05$) among the I-I, PM-PM, M-M, RI-RM and LI-LM distances.

DISCUSSION

The hypothesis in this *in vitro* study that different contents of monomer in the monomer-polymer ratio indicated by the manufacturer could influence tooth displacement of the maxillary complete dentures was not confirmed.

Based on the obtained results, it was possible to observe that there was no statistically significant difference in the anteroposterior and transverse distances between the manufacturer's recommendation (control) and the experimental groups (25% excess or 25% less monomer) for conventional (Table 1) and microwaved resins (Table 2).

Table 1. Means and standard deviations of the distances between teeth and for the conventional resin, in relation to monomer content in monomer-polymer ratio.

Monomer/ polymer ratio	I-I	PM-PM	M-M	RI-RM	LI-LM
Manufacturer	7.21 ± 0.42 a	41.63 ± 0.50 a	53.51 ± 0.59 a	41.69 ± 1.00 a	39.58 ± 1.56 a
+ 25%	7.33 ± 0.46 a	41.60 ± 0.87 a	53.64 ± 0.72 a	41.26 ± 1.22 a	39.53 ± 1.84 a
- 25%	7.66 ± 0.39 a	41.37 ± 0.53 a	53.57 ± 0.50 a	40.78 ± 1.50 a	39.54 ± 1.28 a

Means followed by identical lowercase letters in each column do not differ statistically by the Tukey's test (5%).

Table 2. Means of the distances between teeth and SD for the microwaved resin, regarding monomer content in monomer-polymer ratio.

Monomer	I-I	PM-PM	M-M	RI-RM	LI-LM
Manufacturer	7.39 ± 0.44 a	41.80 ± 0.50 a	53.73 ± 0.49 a	41.93 ± 0.86 a	38.89 ± 1.47 a
+ 25%	7.53 ± 0.48 a	41.41 ± 0.43 a	53.72 ± 0.39 a	40.82 ± 1.31 a	38.99 ± 0.61 a
- 25%	7.20 ± 0.35 a	41.23 ± 0.58 a	53.88 ± 0.41 a	40.78 ± 1.38 a	38.53 ± 0.35 a

Means followed by identical lowercase letters in each column do not differ statistically by the Tukey's test (5%).

Table 3. Means of the distance between teeth and SD in relation to activation types, considering the manufacturer's ratio.

Activation	I-I	PM-PM	M-M	RI-RM	LI-LM
Conventional	7.21 ± 0.42 a	41.63 ± 0.62 a	53.51 ± 0.73 a	41.69 ± 1.38 a	39.58 ± 1.93 a
Microwaved	7.39 ± 0.42 a	41.80 ± 0.53 a	53.73 ± 0.41 a	41.93 ± 1.24 a	38.89 ± 0.89 a

Means followed by identical lowercase letters in each column do not differ statistically by the Tukey's test (5%).

The literature shows that several factors are involved in processing the complete dentures, which would be responsible for the dimensional changes that can cause displacement of the teeth (3,10), resulting changes in the vertical dimension, dental occlusion inaccuracy, and decrease in stability and retention of the denture in use.

Materials for denture flasking have generated controversy in the results on the stability of the teeth. In order to avoid tooth displacement, the dental plaster would be the best choice for denture inclusion because the set and thermal expansions minimize the distortion of the acrylic resin during base polymerization (5).

In the present study, denture inclusion was made with a silicone layer and there was no significant difference in tooth displacement among the groups. This fact seems to show that the silicone has no effect over the linear displacement of the denture teeth, as showed by previous studies (11,12).

Occlusal adjustment is a common clinical procedure after oral setting of the denture in order to correct the increase in the vertical dimension that can occur after the resin polymerization. A classic study showed that the changes in the vertical dimension may vary from 0.000 to 1.49 mm (2). In order to minimize the increase in the vertical dimension of occlusion, it has been recommended the method of injection of the mold. However, both injection and conventional methods may promote contraction in the intermolar distances (8,13), and the flask closure methods also cause different effects on the level of tooth displacement (14).

In order to minimize the dimensional changes that occur in the denture base, it is recommended the use of the RS flask closure system, regardless if the starting of the resin polymerization was immediate or after 6 h of bench storage (8,15).

According to the results of this study, it was not observed significant difference in the distances between teeth when different contents of monomer were used in the monomer-polymer ratio (Tables 1 and 2). However, it was also observed that in all monomer-polymer ratios the dentures polymerized by the conventional method showed a slight tendency for expansion in the IE-ME distance when compared to the microwaved method. This fact shows that small dimensional changes promoted by different polymerization cycles may require different levels of occlusal adjustment (4).

Based on this result, it is possible to assume that the polymerization method and monomer-polymer ratio association was not sufficient to change the linear distance between teeth, probably due to other variables not considered in this study, as for example, the effect of the silicone layer used as denture investment material (11). In addition, dimensional changes may occur

Table 4. Means of the distance between teeth and SD in relation to activation types, considering 25% in excess of monomer.

Polymerization	I-I	PM-PM	M-M	RI-RM	LI-LM
Conventional	7.33 ± 0.46 a	41.60 ± 0.87 a	53.64 ± 1.01 a	41.26 ± 1.22 a	39.53 ± 2.67 a
Microwaved	7.53 ± 0.48 a	41.41 ± 0.43 a	53.72 ± 0.39 a	40.82 ± 1.31 a	38.99 ± 0.61 a

Means followed by identical lowercase letters in each column do not differ statistically by the Tukey's test (5%).

Table 5. Means of the distance between teeth and SD in relation to the different types of activation, considering 25% less of monomer.

Polymerization	I-I	PM-PM	M-M	RI-RM	LI-LM
Conventional	7.66 ± 0.31 a	41.37 ± 0.53 a	53.57 ± 0.57 a	40.78 ± 1.78 a	39.54 ± 1.71 a
Microwaved	7.20 ± 0.35 a	41.23 ± 0.58 a	53.88 ± 0.41 a	40.78 ± 1.38 a	38.53 ± 0.35 a

Means followed by identical lowercase letters in each column do not differ statistically by the Tukey's test (5%).

in the denture base related to the final flask closure. Consequently, these dimensional changes may occur due to stresses released when the flask is removed from hydraulic press and transferred to the metallic clamp (8).

It has been claimed that a post-pressing time to start the polymerization would be recommended in order to promote a better accommodation of the resin mass inside the flask and consequent relaxation of stresses induced on the resin during the pressing (15). It can be assumed that the time of stabilizing of the load applied to the final flask closure for 20 min had allowed the relaxation of stresses induced in the resin mass, probably decreasing the base distortions.

The polymerization cycles influence the content of residual monomer, as well as short cycles allow 3 to 7 times more residual monomer in the mass (16). However, the present study showed that excessive or less monomer in monomer-polymer ratio did not promote a significant effect on the tooth displacement. In this case, both the long polymerization and microwave cycles were sufficient to minimize the effects of the stresses responsible for tooth displacement in all groups.

This way, excess (unnecessary to establish the stoichiometric reaction because the monomer excess volatizes afterwards) or less (enough for the stoichiometric reaction because the manufacturer recommends greater quantity of monomer to make the manipulation easier) monomer content indicated by the manufacturer promote similar conversion of monomer into polymer. This results in similar monomer conversion and promoted changes in distances between teeth with no statistically significant difference.

Thick denture bases cause a more critical misfit in the posterior palate region, decreasing the retention and difficult the correction of the changes after denture procedure (4). In this study, 2.5-mm-thick bases were used, which could also have contributed to keep the dimensional stability and, consequently, the linear distances between the teeth.

Another fact to be considered in the tooth displacement is the palatal vault form. Dentures made on medium sized vault showed less teeth movement in comparison with shallow or deep palatal vault (3), a condition that can contribute to these results, considering the use of a normal edentulous maxillary arch with no retentions or acute irregularities in the crest.

There was no significant difference in the displacement of the teeth when the conventional and microwaved resins were compared in relation to monomer content recommended by the manufacturer (Table 3), 25% excess (Table 4) and 25% less monomer content (Table 5).

This fact may be associated with tooth displacement due to the level of residual monomer that is related to the polymerization time and temperature. The result of the present study suggests that different polymerization cycles did not influence tooth displacement, even when different polymerization methods and curing processes have different effects on residual monomer content (18). The residual monomer is inevitable for all PMMA-based products regardless of the polymerization conditions used (19), and insignificant residual monomer content remains after storage in water (20).

It would be interesting if future studies were developed aiming a better understanding of the effect of monomer-polymer ratio in the displacement of teeth on complete dentures. A variable to be studied would be to determine the content of residual monomer resulting from the proportions analyzed in this present study. Furthermore, the effect of monomer-polymer ratio on some mechanical properties of the acrylic resin could also be of great value in determining the dimensional changes of the base and distance between teeth.

Based on the discussed results and considering the limitations of this study, it may be concluded that excessive or less monomer in the monomer-polymer ratio and polymerization types (conventional and microwaved) did not change the linear distance between teeth.

RESUMO

O propósito neste estudo foi verificar a movimentação linear de dentes em prótese total superior confeccionada com resina acrílica, proporcionada com conteúdo de monômero indicado pelo fabricante, com 25% de excesso ou com 25% a menos de monômero, nas técnicas de polimerização convencional e por microondas. Foram confeccionados 30 modelos, representando uma arcada maxilar desdentada com rebordo normal. As bases de prova e os planos de orientação foram confeccionados em cera e o conjunto montado em articulador semi-ajustável relacionado com um modelo inferior dentado. Depois da montagem dos dentes artificiais, a prótese foi moldada com silicone para duplicação das demais próteses. Foram confeccionados pontos referenciais para mensurações das distâncias entre os dentes, as quais foram analisadas com microscópio comparador linear antes e depois da desinclusão das próteses. As resinas acrílicas foram prensadas de modo convencional, alterando somente o conteúdo de monômero na proporção monômero-polímero recomendada pelo fabricante. Os dados da distância entre os dentes foram submetidos à análise de variância e ao teste de Tukey (5%). Não

houve diferença estatística entre os grupos com quantidade de monômero recomendada pelo fabricante e os grupos com 25% a mais ou 25% a menos de monômero, tanto na polimerização convencional como por microondas. A alteração do conteúdo de monômero e o tipo de polimerização (convencional ou por microondas) não exerceram influência na movimentação dental nas distâncias transversal e ântero-posterior.

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