Influence of Flask Closure and Flask Cooling Methods on Tooth Movement in Maxillary Dentures

Rafael L.X. Consani, DDS, MSc, PhD;[1] Saide S. Domitti, DDS, MSc, PhD;[2] Marcelo F. Mesquita, DDS, MSc, PhD;[3] and Simonides Consani, DDS, MSc, PhD[4]

Purpose: **This study investigated the tooth movement of standardized simulated dentures processed by traditional closure or the new Rafael Saide (RS) tension system when cooled in the curing water itself or in curing water followed by bench storage for 3 hours.**

Materials and Methods: **Forty stone casts were formed from a mold of an edentulous maxillary arch. The wax denture record bases were made on the casts; the height of the wax rim occlusion was 20 mm in the labial sulcus of the cast and 10 mm in the posterior region. The upper stone cast was mounted on a Mondial 4000 semi-adjustable articulator with wax rim interocclusal references in relation to the lower stone cast teeth. Metallic pins were placed in the incisal border of the maxillary central incisors (I), labial cusp of the first premolars (PM), and mesiolabial cusp of the second molars (M). The incisor-to-incisor (I–I), premolar-to-premolar (PM–PM), and molar-to-molar (M–M) transversal distances and left incisor-to-left molar (LI–LM), and right incisor-to-right molar (RI–RM) anteroposterior distances were measured before and after denture polymerization with an optical microscope with a tolerance of 0.0005 mm. For traditional closure, the dentures were flasked conventionally in standard metallic flasks, which were afterward placed in spring clamps. For the new RS system closure, the flasks were pressed between the metallic plates of the tension system after the final closure. The Clássico heat-polymerizing acrylic resin dough was packed in the flasks under a final packing pressure of 1.250 kgf. Twelve hours after flask closure, the dentures were polymerized in a moist heat-polymerizing cycle for 9 hours at 74°C. The denture was deflasked after cooling in the water of the polymerizing cycle (groups A and C) or in the water of the polymerizing cycle and then bench-stored for 3 hours (groups B and D). Collected data were analyzed with analysis of variance and Tukey's test ($p < 0.05$).**

Results: **There was no statistically significant difference ($p > 0.05$) between the conventional and new RS system closure methods for the transversal distances after polymerization in all studied groups. The anteroposterior distances did not change with deflasking after water bath cooling. There were statistically significant differences ($p < 0.05$) in the anteroposterior distances with deflasking after water bath cooling and then bench storage for 3 hours.**

Conclusion: **Tooth movement was similar in dentures processed by traditional closure and by the new RS tension system, with the exception of the anteroposterior distances when the flasks were cooled in their own curing water and bench-stored for 3 hours.**

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INDEX WORDS: **tooth movement, maxillary complete denture, flask pressure, flask cooling**

[1]From State University of Campinas, Piracicaba School of Dentistry, São Paulo, Brazil.

[2]Assistant Professor, Department of Prosthodontics.

[3]Professor, Department of Prosthodontics.

[4]Professor, Department of Restorative Dentistry.

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Correspondence to: Dr. Rafael L.X. Consani, DDS, MSc, PhD, Rua Dr. José Vizioli, 255 13400-450-Piracicaba, SP, Brazil. E-mail: rconsani@merconet.com.br

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A CLASSIC STUDY concerning complete denture vertical dimension was conducted several decades ago. At that time, it was demonstrated that excessive pressure during packing might increase the vertical dimension of the denture, which may also vary with the type of investment used.[1]

Although the increase in vertical dimension of occlusion might appear quite critical, the amount of tooth shift needed to cause it is considered small. Thus, the raising of the incisal guide pin or an increase in the vertical dimension of occlusion of 1.0 mm may be the result of 0.25 mm in tooth shift.[2]

The most likely cause of the increase of the vertical dimension of occlusion is the excess of acrylic resin in the mold at the time of flask final closure; however, regardless of the amount of force that can be applied with the flask press, a small amount of dough will remain,[3] and the larger the amount of dough, the greater the increase in the vertical opening in the processed denture.[4] A special flask with a central exhaust or escape for the resin was described in order to avoid increasing the vertical dimension of dentures during packing and processing.[5]

The first pour of the investment does not alter the position of the teeth relative to the cast inside the flask. The resultant tooth position depends upon the angle of the cast tilt, and the way in which the final occlusal pattern is affected by the tooth movement contributes to the increase in the vertical dimension of the denture;[6] however, movement of both teeth and cast occurs in the vertical plane, and this movement is a consequence of the setting expansion of the plaster required between the base of the flask and the cast. When the second pour of the investment is made, the position of the cast is not altered, but the position of the teeth is changed by the plaster expansion.[7] Apparently, the teeth are an important factor in the distortion of dentures that occurs during heat processing. The teeth are held firmly in place by the gypsum investment, which probably induces complex stress in the denture base. The resulting restriction may also contribute to the inhibition of the tooth shift.[8] Although the distortion may occur in the denture base, the anteroposterior distance may be maintained unmodified due to the interproximal contact of the artificial teeth.[9] A previous study demonstrated no significant difference in the linear dimensional change when the denture was slowly cooled in the water bath.[10]

An investigation into tooth movement performed decades ago showed that tooth displacement was, in fact, mold expansion;[11] however, the dimensional changes due to the elastic recovery of the residual stress released by deflasking[12] are probably responsible for the amount of vertical opening found in dentures processed with silicone investment, which was approximately the same as for those processed with the all-gypsum technique.[13]

Although the shrinkage occurring in the acrylic resin during the polymerization is an important factor in the denture procedure as a whole,[14] another important cause of denture bases shrinkage is the thickness of the resin, and the dimensional change depends on the location within the flask.[15] The base thickness is particularly important, since it governs the stiffness, limiting the level of contraction of the dentures.[16] It has been reported that the average molar-to-molar shrinkage of thin bases is approximately twice that of thick dentures.[17] In contrast, another study showed that an increase in the molar-to-molar distance was found in both the thin and thick denture bases, but the magnitude of tooth movement was more in thick dentures.[18]

Although the discrepancies for an intermolar distance might be considered small and the misfit clinically undetectable,[19] the dimensional accuracy of the denture base has been demonstrated to also be dependent upon the commercial types of the acrylic resin.[20] In addition, a previous study has shown that the changes occurring in the acrylic resin base are not easily corrected after processing, although the smaller posterior tooth shift may be corrected by occlusal adjustment in the remounting clinical procedure.[21] The denture discrepancies are present on transverse and midline sections of stone casts with the dentures in the central portion of the posterior border,[22] and remain a current and critical problem in the denture processing.[8,18,20,21,23]

Recently, a new RS tension packing system demonstrated decreased dimensional changes in the simulated maxillary denture bases processed with moist heat-polymerization when compared with traditional spring clamps.[24]

The purpose of this study was to investigate the differences between the tooth movement of standardized simulated maxillary dentures processed by traditional closure with spring clamps and those processed using the new RS tension system, after cooling in the dentures' own curing water or curing water and bench storage for 3 hours.

Materials and Methods

Forty maxillary dentures were constructed from similar type III dental stone casts (Herodent Soli-Rock, Vigodent, Rio de Janeiro, RJ, Brazil) simulating an arch without irregularities in the alveolar ridge crest. Wax denture record bases with a thickness of 2 mm[20] were made on the respective casts, with occlusal wax rim heights of 20 mm in the labial sulcus of the cast and 10 mm in the second molar region. The occlusal rim heights were determined according to the Trubyte Biotone acrylic teeth size (Dentsply, Petrópolis, RJ, Brazil), model 3 P, 32 L, and 33° for normal mesiodistal contacts. The maxillary denture and lower stone cast with teeth were mounted in a Mondial 4000 semi-adjustable articulator (Bio-Art Dental Products, São Carlos, SP, Brazil) after the adjustment of the pattern references of the articulator (Bennett angle of 15°, condylar guidance of 30°, and the intercondylar distance in M point). To accurately mount all dentures on the articulator, similar V-shaped notches were carved in the base of the maxillary casts.

The maxillary left anterior teeth were arranged in line with the carved wax-rim to serve as a guide for the central and lateral incisors (I), and canine positions. The same procedure was performed in the right arch. The arrangement of the posterior teeth began with the first premolar (PM) until the second molar (M). The same procedure was carried out in the right arch. The anterior teeth interocclusal relationship was arranged with vertical overlaps of 1 mm; in the horizontal overlap, the upper and lower anterior teeth were in centric occlusion. The posterior teeth were arranged in Angle class I.

Metallic reference pins were placed in the incisal border of the maxillary central incisors, labial cusp of the first maxillary PMs, and mesiolabial cusp of the second maxillary molars. The incisor-to-incisor (I–I), premolar-to-premolar (PM–PM), and molar-to-molar (M–M) transversal distances; and left incisor-to-left molar (LI–LM) and right incisor-to-right molar (RI–RM) anteroposterior distances were measured before polymerization to confirm the standard of the teeth arrangement in all dentures. The data submitted to analysis of variance (ANOVA) and Tukey's test showed no statistically significant difference ($p > 0.05$). Thus, all distances considered were similar before denture processing. Under these conditions, the changes in tooth distances may result from the flask closure and flask cooling techniques used. After denture processing, the control for the RS flask closure technique was the conventional spring pressure technique. The distance measurements were made with an STM model optical microscope (Olympus Optical Co., Tokyo, Japan) with a tolerance of 0.0005 mm.

The maxillary dentures were flasked conventionally in dental stone (Herodent Soli-Rock), using a standard metallic flask (J. Safrany Metallurgy Co., São Paulo, Brazil). The waxed dentures were softened for 10 minutes in boiling water. The two halves of the flask were separated, the wax removed, and the stone cleaned with liquid detergent (ODD, Bombril-Cirio, São Paulo, SP, Brazil) and boiling water. After bench cooling, one coat of sodium alginate (Clássico Dental Products, São Paulo, SP, Brazil) was used as a separating medium. The dentures were randomly assigned to the following groups ($n = 10$ each): Group A, acrylic resin flasking with the conventional flask closure technique and deflasking after cooling slowly inside the water bath; Group B, acrylic resin flasking with the conventional flask closure technique and deflasking after cooling slowly inside the water bath, and then bench storage for 3 hours; Group C, acrylic resin flasking with the new RS flask closure technique and deflasking after cooling slowly inside the water bath; and Group D, acrylic resin flasking with the new RS flask closure technique and deflasking after cooling slowly inside the water bath, and then bench storage for 3 hours.

The heat-polymerized acrylic resin (Clássico Dental Products), based on polymethylmethacrylate, was prepared with a mixing ratio of 35.5 g polymer to 15 ml monomer, according to the manufacturer's instructions. The prepared dough was packed in plastic stage in all group assignments. A plastic sheet was used as a separating medium between the gypsum and the acrylic resin during the initial flask closure under a load of 850 kilograms-force (kgf) in a hydraulic press (Linea H, São Paulo, SP, Brazil). After the flask was opened, the plastic sheet was removed, and the acrylic resin excess was trimmed.

For the conventional flask pressure technique groups (A and B), the flasks were placed in traditional spring clamps after final pressing in a hydraulic press (Linea H) under a load of 1.250 kgf for 5 minutes. In the modified technique groups (C and D), the flasks were positioned between the two plates of the new RS system.[24] This assembly is composed of two iron plates, each $150 \times 40 \times 8$ mm. A 9-mm diameter screw was soldered into each end of the lower plate; two corresponding holes with a 10-mm diameter cross section were present in the upper plate. During the definitive flask closure, the screws of the lower plate were fitted into the holes of the upper plate and, after hydraulic flask pressure, the screw-nuts were strongly tightened to the screws before press releasing. This procedure maintains constant metal-to-metal contact on the flask halves.

Twelve hours after the final flask closure, the dentures were polymerized in a thermopolymerizing unit (Termotron Dental Products, Piracicaba, SP, Brazil), with the water bath at 74°C for 9 hours, in accordance with the manufacturer's instructions. The unit was programmed to raise the temperature to 74°C at 1 hour, and then maintained at 74°C for 8 hours. After polymerizing, the flasks were cooled according to the trial groups, deflasked and polished, and the tooth distances measured using the same procedure as that used before denture polymerization. Collected data (in mm) were examined using one-way ANOVA and pairwise multiple comparison procedures (Tukey's test) at the $p < 0.05$ level of significance.

Results

The denture tooth shift in the I–I, PM–PM, and M–M transversal distances, and RI–RM and LI–LM anteroposterior distances, according to the flask pressing and flask cooling methods, are given in Table 1. There was no statistically significant difference ($p > 0.05$) between the conventional and new RS system closure methods in tooth shift with deflasking after water bath cooling for both transversal and anteroposterior distances. No statistically significant difference was found for the transversal distance means ($p > 0.05$). In contrast, a statistically significant difference ($p < 0.05$) was observed between the anteroposterior distance means in the dentures deflasked after water bath cooling and then bench storage for 3 hours.

Discussion

Although the tooth shift responsible for increases in vertical dimension is small, tooth movement has long been considered a critical factor in occlusal maladjustment during denture processing.[2,8,9,18] Most of the smaller changes occurring in molar tooth shift can be corrected by occlusal adjustment during the remounting clinical procedure,[21] and the changes in vertical dimension produced by different investing mediums appeared to be well within the range of adjustment by selective grinding after denture processing.[25] However, these changes remain a current and critical problem in complete denture construction.[19,20,24,26]

According to classical studies, tooth shift occurs as a result of several complex factors, such as investment plaster types,[1] load during the final flask closure,[2] excess of acrylic resin after final flask pressure,[4] plaster expansion used in the flask investment,[7] stone mold expansion,[11] tilt of the cast inside the flask,[6] and elastic recovery of the residual stress released by deflasking during cooling.[12]

Another cause for M–M contraction is the thickness of the base,[18] since the thickness governs its stiffness, limiting the degree of shrinkage of the dentures.[16] After removal from the cast, polymerized dentures with thicker cross sections were stiff enough to prevent release of some of the residual stress,[27] resulting in an average M–M shrinkage of thin dentures of approximately twice that of thick dentures.[17]

From a technological standpoint, the use of an analog-to-digital interface with a digital computer is considered advantageous, since this system presents a complete analysis of the three-dimensional pattern of distortion.[28] The method of measurement used in this study involves the limitations concerning the relative distortion analysis. Consequently, the global displacement summing of all points from the original position was not determined, unless the movement of each individual distance had been measured with an accuracy of 0.0005 mm. This is an easy method, capable of defining a standard method to analyze

Table 1. Tooth Distance Means—Flask Pressure and Flask Cooling Methods (mm ± Standard Deviation)

		Tooth Distances				
Flask Cooling	*Flask Pressure*	*I–I*	*PM–PM*	*M–M*	*RI–RM*	*LI–LM*
Water	Conventional	7.23 ± 0.32 a	39.76 ± 0.30 a	52.84 ± 0.72 a	37.32 ± 1.24 a	35.20 ± 1.19 a
	RS	7.17 ± 0.26 a	39.80 ± 0.43 a	53.10 ± 0.57 a	38.04 ± 0.57 a	34.17 ± 0.86 a
Water + bench	Conventional	7.06 ± 0.32 a	39.79 ±0.45 a	52.92 ± 0.83 a	36.82 ± 0.96 b	35.56 ±1.46 a
	RS	7.27 ± 0.20 a	39.96 ± 0.60 a	53.17 ± 0.62 a	37.70 ± 0.75 a	34.09 ± 0.70 b

Means followed by a different lowercase letter in the same column in each flask cooling method were significantly different ($p < 0.05$).

linear displacement between two points, without involving three-dimensional distortion study (coordinate axes). The linear distortion may be measured from the individual pin movements occurring in different locations of the denture. In this method, the linear displacements were measured with a better level of accuracy than is commonly accepted for clinical application.

This study demonstrates the great complexity of the process and clarifies the presence of mean values with no significant statistical difference in the majority of distances between the teeth, when the conventional flask pressure was compared with the new RS system method (Table 1). Thus, despite previous studies that showed the influence of several factors, such as the physical changes of the acrylic resin due to its own cooling,[14] and the complex system of concentration and release of stresses causing distortion of the base,[12] these conjugated factors were not sufficient to cause differences in tooth movement in the transversal direction between both flask pressure techniques used in this investigation.

The restriction of the plaster mold is also a factor causing inhibition of tooth shift.[7] The thermal behavior of the acrylic resin below the glass transition temperature may be at least partially responsible for the small shift, when the teeth are fitted in both investment plaster and polymerized acrylic resin bases. Thus, when thermal shrinkage of the acrylic resin occurs, the teeth are held firmly in place, inducing complex stresses in the denture base.[8]

The relaxation due to deflasking causes distortion of the base, which is partly dependent on the acrylic resin alone. Free from the investment plaster, the tooth movement would then be minimal, but always influenced by the distortion of the acrylic resin base due to release of residual stress remaining from the thermal contraction.

Although this study did not investigate vertical tooth movement, previous research[29] has shown that the premolar and molar 33° teeth exhibited greater increase in vertical movement than 0° teeth. This increase depends on the investment type, and no significant pattern of individual vertical tooth movement was observed.[29] Other relevant results regarding the denture processing techniques have demonstrated three-dimensional changes in the position of the teeth[30]; the artificial teeth would, therefore, maintain an unmodified anteroposterior distance due to the interproximal contact,[9] independently of the base contraction occurring in an anterior direction because of the anchoring effect of the labial residual ridge.[31] In addition, no significant difference in the anteroposterior or mediolateral horizontal tooth distances was revealed between compression and injection molded complete dentures,[32] and no significant changes in the polymerization contractions (intermolar widths) were verified in complete dentures fabricated by conventional method, injection molding, and microwave processing.[26]

In this study, the anteroposterior tooth distances were maintained unmodified after denture processing when the flasks were slowly cooled in the water bath itself (Table 1). Probably, the cooling period in the curing water, about 5 hours, was sufficient to release some of the residual stress induced during the denture processing in both flask closure methods. Similar results showed no significant difference in the linear dimensional change between points when the denture base was allowed to cool slowly to room temperature in the water bath.[10]

The RS tension system was able to produce an accurate denture base and to minimize the inaccuracies associated with the conventional packing technique, particularly in the posterior palatal zone.[24] This influence was not observed in the distances of the transversal teeth when the dentures were cooled by both methods, and in the distances of the anteroposterior teeth in the water bath cooling method.

Conversely, when the flask was cooled in the water bath and then bench-stored for 3 hours, the anteroposterior distances demonstrated statistically significant differences between the conventional and the new RS system closure methods (significantly lower in the RI–RM distance for conventional pressing system, and significantly lower in the LI–LM distance for RS pressing system).

These linear dimensional changes that occurred in the tooth shift by the influence of the flask closure and flask cooling are complex and difficult to explain. Considering that it is possible to achieve greater tooth shift on one side of the denture than on the other,[2] and that the discrepancies in the transverse and midline sections of the stone casts with the denture bases in the posterior border[22] appear to be of little significance on the overall tooth shift,[19] the most likely explanation for these findings is based on the fact that dimensional changes taking place during denture processing remain complex,[9,29-32] are not uniform,[20-22] and depend on the location within the flask.[6,7,15]

Considering that this study indicates that tooth shift is also related to a combination of flask cooling and closure methods, further investigations are required.

Conclusion

Tooth movement was similar in dentures processed by traditional closure and dentures processed by the new RS tension system, with the exception of the anteroposterior distances when the polymerized flasks were cooled in their own curing water and then bench-stored for 3 hours.

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