The Effects of Different Investment Materials on Dimensional Accuracy and Surface Roughness of Thermosens Maxillary Complete Dentures

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ABSTRACT

Background: Limited data are available on the dimensional stability and surface roughness of ThermoSens, which is a material used in denture processing. This study aimed to measure the vertical teeth changes and surface roughness of ThermoSens dentures prepared using three different investment materials.

Materials and methods: For the dimensional changes test, 30 complete maxillary dentures were prepared using different investment methods: group I, dental stone; group II, silicone putty; and group III, a mixture of dental stone and plaster (ratio, 1:1; n = 10 for each group). Eight screws where inserted, four for each side of the denture: two were attached to the buccal surface of the canine and first molar, and the other two were attached in the flange areas of the canine and first molar in line with the previously mentioned screws. Measurements were made using a micrometer microscope in the wax stage before flasking and in the deflasking stage. The above investment techniques were also used to prepare samples for a surface roughness test (n = 10 per group). These samples were prepared according to the specifications of the American Dental Association. Data were examined using analysis of variance (ANOVA) and the least significant difference (LSD) test.

Results: One-way ANOVA and LSD revealed that dimensional changes significantly differed among all groups, except that the vertical teeth changes on the left side did not differ between groups I and II for both the canine and molar regions. Surface roughness was significantly higher in group I than in group II, and in group III than in group II.

Conclusion: The use of putty silicone for investing ThermoSens complete dentures reduced dimensional changes and resulted in dentures with a better fit. Surface roughness could be reduced by the addition of a putty silicone layer over the denture before the addition of the second investment layer during denture processing.

Keywords: Investment material, dimensional changes, surface roughness, ThermoSens. **(J Bagh Coll Dentistry 2015; 27(3):1-7).**

INTRODUCTION

Denture bases dimensional stability during processing and in service is important for dentures to accurately fit the underlying foundations and satisfaction of the patient. In general, if the denture is properly processed, the original fit and dimensional stability are good, regardless of the denture base material used.[1] Currently, poly(methyl methacrylate) (PMMA) is widely used in prosthetic dentistry for the construction of complete and partial dentures.[2] Well-known allergens in dentures include residual monomers, peroxides and metals. In patients with PMMA hypersensitivity, the denture base should be constructed from other polymeric materials to which the patient is not allergic.[3]

Over the past 40 years, many denture-production techniques other than pressing and/or molding dentures from an MMA–PMMA system have been developed, from light-cured paste systems to microwave polymerization, and from the injection molding technique to thermoplastic systems.

One of the injection molding technique advantages, is to allow directional control of the polymerization process through the flask design, and involves a constant flow of new material from the sprue, thereby compensating for polymerization shrinkage.[4] Thermoplastic materials, such as polyamides (nylon plastics), were introduced as early as the 1950s. With time, several types of thermoplastic materials were developed: acetal, polycarbonate, acrylic and nylon (resin).[5,6]

The first thermoplastic nylons for dental prostheses, Valplast (Valplast Int. Corp., Long Island City, USA) and Flexiplast (Bredent, Germany), were introduced in 1956.[7,8] Different types of prostheses can be fabricated from these materials via the injection-molding technique,[9] which is used for the fabrication of flexible denture-base prostheses.[10] Fluid resin is allowed to flow into the mold cavity of these systems through sprues created using sprue formers. The resulting products are completely free of residual monomers, accelerator systems and stabilizers. Moreover, the thermoplastic products are always homogenous in composition, and they respond consistently during processing. Finally, these thermoplastic materials have no adverse impact on

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the technician or the dental laboratory due to the absence of hazardous materials.[11,12] Thermoplastics are superpolyamides that belong to the nylon family. Nylon can be defined as a resin derived from dicarboxylic acid, diamine, amino acid and lactams.[13] The injection-molding technique is used for the fabrication of flexible denture-base prostheses, which can be reversibly liquefied upon heating. The molten material is placed in a mold and allowed to cool down. A range of thermoplastic materials are used in dental mechanics.[14]

A new material called ThermoSens is superior to standard polyamide materials. The flexibility of this material can be controlled, and its shrinkage is extremely low. Owing to its composition, a homogenous color can be achieved, making this material suitable for the preparation of full dentures. The purpose of this study is to compare vertical artificial teeth movement and surface roughness between complete maxillary ThermoSens dentures prepared by three different investment materials: (a) dental stone, (b) silicone putty (on the outer surface of the denture) and (3) dental stone mixed with plaster of Paris (ratio, 1:1).

MATERILS AND METHODS

A complete maxillary denture with acrylic teeth (Major, Italy) was made using a master cast made from an ideal negative rubber mold represented the upper edentulous arch by pouring type III dental stone (Zhermack Elite Stone, Italy). The record base was formed from +thermoplastic acrylic cakes (BIOCRYL, Iserlohn, Germany) and manipulated using a Biostar machine. The record base had an even thickness of 2 mm. A horse shoe–shaped block of wax was attached to the record base to form the occlusion rim. The wax was shaped such that the length from the highest area of the labial flange (canine eminence) to the occlusion edge was 22 mm and the length from the highest area of the buccal flange (first molar region) to the occlusal plane was 18 mm. The width of the rim was approximately 4 mm anteriorly and 7 mm posteriorly.[15] The maxillary cast was mounted on the articulator by the aid of a mounting plate, and maxillary anterior and posterior acrylic teeth were arranged in a monoplane occlusal scheme. The maxillary denture was completely waxed. The sample was removed from the articulator, and three wax sprues were prepared. Two of these sprues were attached to the posterior area of the maxillary tuberosity, distal to the second molar, and the third sprue was attached to the midline of the posterior part of the palate (Fig. 1).

Figure 1: Three wax sprues are attached to the posterior part of the maxillary denture.

Preparation of duplicated models:

Duplication of the simulation denture was done by using a pourable silicone material (Vertex™, Castasil 21) that is meant to be used for the duplication of models supported by a plastic container that provides rigidity for the duplicating material (Fig. 2).

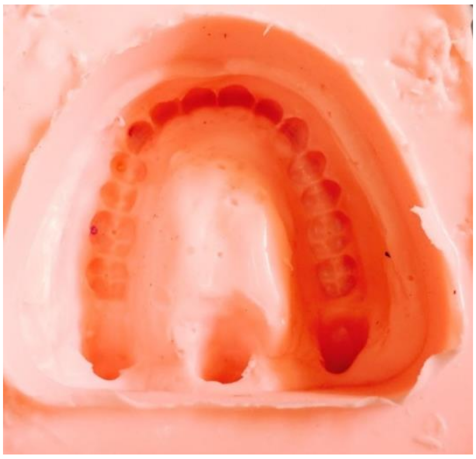

Figure 2: The denture is duplicated using a pourable silicone duplicating material.

Thirty identical maxillary wax dentures were prepared by placing the same size set of teeth into the silicon mold, and then pouring the molten base plate wax into the mold, which was leaved to cool at 37° C for 2 hr before removal. This provided a standard wax simulation of a maxillary denture and thereby minimized variations in polymerization due to the shape and size of the dentures specimens.

Vertical reference point preparation

One metallic reference point placed in the canine flange area of the dentures, on the facial surface of the canine, in the first molar flange area and on the buccal surface of the first molar (Fig. 3). These reference points were used for vertical measurements. The first of all a tentative measurements made by the aids of digital vernier caliper to locate the position of the screws at the wax stage before flasking, then a more precise measurements were made by using micrometer microscope to measure changes in the vertical. Measurements before and after flasking procedures.

On the facial surface of the canine and first molar, a line was drawn with a soft marker perpendicular to the occlusal plane and tangential to the distal surface of the canine screw and mesial surface of the molar screw by using a vernier caliper. Another line was drawn perpendicular to the first line, at a distance of nearly 16 mm from the canine and 15 mm from the first molar. Then a screw pin was attached to the intersection of the two lines in the selected teeth (Fig. 3).

Figure 3: Reference point measurements.

Ten dentures were processed for each of the three groups in the study:

Group I: conventional investment (dental stone)

Group II: silicone putty (Vertex^{TM} putty) used on the outer surface of the denture

Group III: dental stone mixed with plaster of Paris (ratio, 1:1)

Processing of the ThermoSens denture base material and vertical measurements

After wax elimination from the denture, we used an injection machine (Vertex^{TM} ThermoJect 22) to inject ThermoSens capsules (Vertex ThermoSens, capsule size XL) into a flask, which was then allowed to cool to room temperature. Once cooled, the flask was opened, and the denture was attached to the base of a surveyor, so that the reference points could be observed under a microscope. The distance between the following reference points was measured: (a) right canine–right screws, (b) right molar–right screws, (c) left canine–left screws and (d) left molar–left screws (Fig. 4).

Figure 4: Processed denture with the screws attached at the canine and molar region bilaterally

.**Roughness test**

For the surface roughness test, we prepared 30 specimens with dimensions of 65 mm × 10 mm × 2.5 mm (length, width and thickness, respectively) by using ThermoSens capsules (Vertex ThermoSens, capsule size XL). Ten samples were assigned for each of the three groups mentioned in the dimensional changes test (American National Standards Institute/American Dental Association specification no. 12).

RESULTS

Dimensional changes

The means, standard deviations, standard error, and minimum and maximum values of the dimensional measurements in all groups are shown in Table 1. One-way analysis of variance (ANOVA) revealed significant differences ($P < 0.05$) in all measurements among all groups (Tables 2 and 3). Both canine and molar region measurements in group III significantly differed from those in groups I and II (Tables 4 and 5). The data for the right canine and molar regions, but not the left regions, significantly differed between groups I and II.

Roughness test

The mean, standard deviation, and minimum and maximum values of surface roughness for groups I, II and III are presented in Table 6. The mean roughness value was higher in group I (dental stone investment, 1.53 µm) than in group II (silicone putty, 1.31 µm). The highest mean roughness value was observed in group III (mixture of dental stone and plaster of Paris, 1.61 µm).

One-way ANOVA table (Table 7) with the least significant difference (LSD) test showed that surface roughness was significantly influenced by the material used in denture processing ($P < 0.05$). Significant differences were found between groups I and II ($P < 0.012$) and groups II and III ($P < 0.001$), but not between groups I and III ($P < 0.362$); (Table 8).

DISCUSSION

The dimensional characteristics of processed denture bases are affected by many factors, such as the type of acrylic, type of investment material, method of resin introduction and temperature used to activate the polymerization process.[15]

In this in vitro study, all laboratory dentures were measured in the wax stage and deflasking stage to determine the effect of polymerization shrinkage of the ThermoSens resin and the effects of investment materials on denture dimensions.

Changes in teeth vertical measurements of complete dentures

Group II showed less shrinkage in the dimensions than did groups I and III. Table 1 show the effects of different investment methods on the polymerization of ThermoSens. The lowest mean difference was observed in group II (silicone putty), while the highest was observed in group III (mixture of plaster and stone). These results may be attributable to the type of investment material and its effect on the amount of stress relaxation. The harder the investment material, the more difficult is the deflasking procedure, which results in additional stress within the resin that is subsequently released. This explains why the least amount of shrinkage was detected in the group-II samples. Silicone putty has a high tear resistance [15] and can therefore be deflasked without difficulty by using a scalpel to cut the putty and liberate the sample. In comparison, groups I and III, which involved gypsum investment, showed more shrinkage, as the deflasking procedure was the most difficult. These results are inconsistent with those reported in some studies,[16–18] but agree with those reported by Duke et al.[19] These differences could be attributed to the use of different denture base materials and measurement methods in different studies.

In group II, the right and left vertical distances in the molar region were similar. This finding could be attributed to the less shrinkage of the resin, as silicone showed better dimensional stability than did dental stone, which expanded after processing. In the canine region, the distances differed between the right and left sides. This may be due to the position of the cast and denture within the flask, as stated by Wolfaardt et al.[20] Alternatively, it could be attributable to the position in the injection machine. The above results are inconsistent with those reported by Abd,[16] who found greater differences in the molar areas.

The differences in the vertical dimensions in the canine and molar areas between the stages of waxing and processing were highly significant on both the right and left sides (Tables 2,3,4 and 5). These results may be attributable to the amount of polymerization shrinkage, thermal contraction of the resin and mold, and the stress released during deflasking. These findings agree with those of Abd,[16] who reported that polyvinyl siloxane duplicating materials produce better dimensional stability, which is affected by the type of investment method used.

Tables 3 and 5 show the differences in mean values of the dimensional measurements between the experimental groups. The differences in molar and canine measurements between groups I and III, and groups II and III were highly significant for both the left and right sides. This could be attributable to the effect of stress relaxation due to thermal contraction and polymerization contraction of putty silicone, which is mainly caused by the cross-linking and rearrangement of bonds within and between polymer chains.[21,22]

The molar and canine measurements on the right, but not those on the left, significantly differed between groups I and II. These findings may be attributed to the investment material used, i.e., type III dental stone, which has a setting expansion of 0.15%–0.25%. [21] Once the investment material is set, the mold expands only slightly, as the effect of the setting expansion of gypsum is reduced by confining it within the flask.[23] The expansion of the gypsum mold exceeds the polymerization shrinkage of putty silicone, leading to the expansion of the measured distances. The non-significant differences could be attributed to the erratic release of internal stress induced during the deflasking procedure. The magnitude of dimensional change depends on the conditions of molding, the shape of the mold and the direction of measurement.

Surface roughness

The ThermoSens denture base material is more flexible than the commonly used PMMA. However, the material polish-ability has not been examined thoroughly. The surface roughness (Table 6) was lowest (1.31 μm) in group II and highest in group III (1.61 μm); the roughness in group I was 1.53 μm. These results indicated that the type of investment material affected the roughness of the polishing surface of the dentures. However, the roughness of the surface of the ThermoSens material before polishing significantly differ between groups I and II (Table 8), and this may be due to the use of diffrenet investment materials (type III dental stone and silicone putty). The non-significant difference between groups I and III (Table 8) also may be attributable to the use of different investment materials (stone vs. mixture of dental plaster and stone). The addition of plaster, which shows more dimensional changes and a more porous surface, affected the surface roughness. Our findings were consistent with other studies[24–28] that have found that the average roughness of unpolished polyamide is 1.111 ± 0.178 μm**.** It is difficult to directly compare roughness values with other studies because of differences in methodology including; polishing methods, apparatus used for measuring surface roughness and material types used.

Groups II and III showed highly significant differences in surface roughness (Table 8), possibly due to physical properties differences of the investment material used during processing and the use of the injection procedure and overheating. The injection molding temperature, pressure and cooling rate must be standardized for optimal denture-surface roughness

In conclusion, the use of silicone putty on the outer surface of complete dentures before the investment of the second layer will reduce the dimensional changes and surface roughness of the ThermoSens denture base material.

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الخلاصة:
مادة الثرموسنس تستخدم في تجهيز أطقم الأسنان الكاملة. أعدت هذه الدراسة بهدف قياس التغيرات العمودية الحاصلة بالأسنان وخشونة سطح الثرموسنس المستخدم في تجهيز أطقم الأسنان باستخدام ثلاث مواد غامسه مختلفة. ووجد إن استخدام معجون السيليكون كمادة غامسه للثرموسنس المستخدم في تجهيز أطقم الأسنان الكاملة خفضت التغييرات الأبعاد وقللت من خشونة الأسطح. وبذلك يمكن تخفيض خشونة السطح من خلال إضافة طبقة المعجون سيليكون على الأسنان قبل إضافة الطبقة الغامسه الثانية خلال تجهيز الطقم.

Table 1: Descriptive statistics in all groups included in the vertical change in the measurements.

		Groups	N	Mean (mm)	Std. Deviation	Minimum	Maximum
Molar Measurements	Right	Group I	10	0.28	0.133	0.17	0.50
		Group II	10	0.14	0.063	0.05	0.20
		Group III	10	0.59	0.066	0.50	0.65
Molar Measurements	Left	Group I	10	0.25	0.092	0.14	0.35
		Group II	10	0.14	0.066	0.08	0.25
		Group III	10	0.55	0.111	0.40	0.70
Canine Measurements	Right	Group I	10	0.23	0.075	0.15	0.35
		Group II	10	0.14	0.041	0.10	0.20
		Group III	10	0.53	0.057	0.45	0.60
Canine Measurements	Left	Group I	10	0.20	0.095	0.10	0.30
		Group II	10	0.16	0.041	0.10	0.20
		Group III	10	0.52	0.103	0.35	0.60

Table 2: One-way ANOVA of right and left canine measurements.

		Sum of Squares	Df	Mean Square	F	Sig.
Right Side	Between Groups	0.834	2	0.417	130.919	HS
	Within Groups	0.086	27	0.003		
	Total	0.920	29			
		Sum of Squares	Df	Mean Square	F	Sig.
Left Side	Between Groups	0.764	2	0.382	59.64	HS
	Within Groups	0.173	27	0.006		
	Total	0.937	29			

Table 3: LSD multiple comparisons test of dimensional changes in the canine region.

		Mean Difference	Sig.
Right Side	Group I-Group II	0.090	S
	Group I-Group III	-0.300	HS
	Group II-Group III	-0.390	HS
		Mean Difference	Sig.
Left Side	Group I-Group II	0.048	NS
	Group I-Group III	-0.312	HS
	Group II-Group III	-0.360	HS

Table 4: One-way ANOVA of right and left molar measurements.

		Sum of Squares	Df	Mean Square	F	Sig.
Right Side	Between Groups	1.077	2	0.538	69.31	HS
	Within Groups	0.210	27	0.008		
	Total	1.286	29			
		Sum of Squares	Df	Mean Square	F	Sig.
Left Side	Between Groups	0.893	2	0.447	58.931	HS
	Within Groups	0.205	27	0.008		
	Total	1.098	29			

Table 5: LSD multiple comparisons test of dimensional changes in the molar region.

		Mean Difference	Sig.
Right side	Group I-Group II	0.144	S
	Group I-Group III	-0.310	HS
	Group II-Group III	-0.454	HS
		Mean Difference	Sig.
Left side	Group I-Group II	0.116	NS
	Group I-Group III	-0.294	HS
	Group II-Group III	-0.410	HS

Table 6: Mean surface roughness (μm), standard deviation, standard error of mean, and minimum and maximum values in all groups.

	Group I	Group II	Group III
N	10	10	10
Mean (μm)	1.53	1.31	1.61
Std. Deviation	0.22	0.19	0.278
Minimum	1.04	1.02	1.005
Maximum	1.89	1.74	2.008

Table 7: One-way ANOVA for surface roughness test

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.731	2	0.365	4.345	HS
Within Groups	2.285	27	0.084		
Total	3.016	29			

Table 8: LSD multiple comparisons test of surface roughness among all groups.

	Mean Difference	Sig.
Group I-group II	0.2224	S
Group I-group III	-0.0785	NS
Group II-group III	-0.3009	HS