Eur. J. Prosthodont. Rest. Dent., Vol.21, No. 3, pp 135-140
Printed in Great Britain

doi:10.1922/EJPRD_1141Abrandabadi06

The Effect of Numbers and Locations of Retentive Holes Placed on Master Casts on Reducing the Polymerization Distortion of the Maxillary Complete Denture

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Abstract - *Polymerization shrinkage is one of the disadvantages of polymethyl methacrylate resulting in distortion of resin denture bases. The aim of this study is to analyze the effect of numbers and locations of retentive holes on reducing polymerization distortion. Forty eight master casts were assigned as: control group (A); one anchoring hole (B); three anchoring holes (C); five anchoring holes (D).The gap distances between the denture bases and casts were measured. The data were analyzed with one-way analysis of variance (ANOVA) followed by the Post-Hoc LSD test. Mechanical anchorage reduced the gap distances in lateral and mid-palate significantly; and this decrease was affected by numbers and locations of anchoring holes significantly.*

KEYWORDS: Distortion, Polymerization, Polymethyl methacrylate, Heat-polymerized, Denture base

INTRODUCTION

The usage of polymers, such as acrylic resins, is increasing day by day and new materials and application methods are being introduced in this field[1,2]. Among the polymer materials in prosthetic dentistry, Polymethyl Methacrylate (PMMA) is the most widely used material for denture bases on account of its optimal physical properties and excellent aesthetics with relatively low toxicity compared to other plastic denture bases[3-5], and it has been used for denture bases since the mid-1940s[5,6].

The closed-flask compression molding method with heat activation in a water bath, has been used for several years, for processing the acrylic polymer of the denture[4]. However, the polymerization shrinkage of the resin in this technique[3,7] results in a gap between the maxillary denture base and master cast[8], which is unavoidable during the processing of the dentures. Beside the polymerization shrinkage, the distortion in denture base can also happen during the cooling of heat-cured denture bases, because the coefficient of thermal expansion of the acrylic resin is higher than gypsum-investing materials[9,10]. Consequently, these adverse effects cause movement of the denture teeth positions and increase the gap between the denture base and underlying mucosa, resulting in an ill-fitting denture[11-13] which will jeopardize the accuracy of the procedure[8,14].

The manifestation of maxillary denture base shrinkage follows a pattern, the flanges draw inward on the lateral aspects of the tuberosities; as a result, the denture base is raised from the palate, and a lack of adaptation occurs mostly in the posterior palatal seal area[6,8,15-17].

Having a good adaptation in complete dentures not only helps having a thin saliva film thickness, but also it completes the peripheral seal of the denture; hence, the shrinkage of denture base material which will lead to a lift off of the base from the cast in the posterior mid palatal area, has to be avoided[8,18-20].

Numerous alternative methods have been developed to increase the adaptation of the denture base and also decrease the volume shrinkage and distortion, e.g. selective-pressure impression technique[21], designing a 1 x 1.5 mm of space in the posterior palatal area (PPSA) on master cast[14], injection molding[22-24], etc. Therefore the adaptation accuracy in the denture bases has become a focus of several studies in removable prosthodontics. One of the methods is the usage of retentive holes in the PPSA of the master cast for anchoring of acrylic resin during denture processing[15]. In this manner the denture base can be held to the cast during polymerization and it will prevent its distortion toward the investing matrix[25]. Therefore, the dimensional changes and denture's distortions will decrease significantly[25,26].

The present study evaluated the effect of numbers and locations of the retentive holes as a mean of anchoring in reducing the gap distances between denture bases and maser casts. The null hypothesis for this study was that the numbers and locations of the retentive holes would not have any effects in the gap distance in posterior palatal area between denture bases and their master casts.

MATERIALS AND METHODS

In this *in-vitro* study, forty eight edentulous maxillary casts without undercuts were duplicated from an impression of an edentulous patient. In order to simulate real clinical conditions, patient's cast was preferred to artificial moulds.

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For preparing the duplicate casts, the reference cast was fixed in the flask, then vestibules were sealed by wax (Cavex set up regular; Cavex Holland B.V, Haarlem, Netherlands) (Figure 1). In order to duplicate the master cast with its art portion, a sheet of wax and a thin layer of tinfoil were adapted to the anatomical and art portion of the master cast. Lastly an acrylic special tray (Acropars 200; Marlic Medical Industries Co., Tehran, Iran) was fabricated by flasking method under pressure. Impressions were taken under pressure by flasking method with a polyether impression material (Impregum; 3M ESPE, Saint Paul, MN). Each impression was used for pouring four casts. Subsequently, another impression was used. Each cast was poured with 250 gram of stone plaster (Elite Model Fast; Zermack, Venice, Italy) and sufficient amount of distilled water suggested by the manufacturer.

Sixty master casts were duplicated with this method. An acrylic template (Meliodent; Heraeus Kulzer, Hanau, Germany) was used to make the height of the master cast and also the orientation of the inferior surface, the same for each cast. Sample size calculations in this study were based on data from a pilot study which Laughlin et al.[25] were used for their study (power factor= 0.8, significance level=0.01). This pilot study had shown the sample size of 12 casts in each test group and a total sample size of 48 casts[27]. Besides, 12 casts were remained un-coded as reserves in case of excluding casts under the procedure.

Forty eight study casts were coded and divided into 4 groups by random number table. Group A was the control group, in which all the stages were done conventionally and without any intervention. In group B, one retentive hole was designed in the midline, posterior to PPSA of the master cast. In group C, three retentive holes were designed, one the same as in group B, and the two others laterally, between the midline and the alveolar ridges. In group D, besides the retentive holes in group C, two additional holes were designed with the distance of 5mm from each other, commencing 15mm from the posterior border and progressing anteriorly. The holes were drilled with an inverted bur with the surface area of 1mm.

To achieve parallelism and uniformity in the preparation of holes, each cast was mounted on a milling machine with a straight hand piece affixed to it and equipped with an inverted diamond bur (Figure 2). Each retentive hole was drilled to a depth of 5mm, using an eccentric motion to make an undercut. For drilling all retentive holes, in the same designated location, an acrylic template (Meliodent Heat-Cure Translucent; Heraeus Kulzer, Hanau, Germany) was used. First the translucent acrylic template was made, then the midline, posterior border of the cast, left and right ridge cusps and the middle of the distance between midline and ridge cusp were marked. Lastly, the 15 mm and 20 mm distance from posterior border of the cast along the midline were marked and the locations for each five retentive holes were designed.

In the next step, a line determining the midline was drawn and extended to the posterior and inferior part of the cast, then with a fissure bur, a groove was placed showing the midline in the inferior part of the cast. Cross sections for each retentive hole for measuring the interface gap were determined in the acrylic template, which were used as a guide for drilling the holes by a line, and then a groove along this line was placed in both left and right art portions of the cast. In this way, cross sections will be made by trimming the casts up to the grooves in art portions. The cross section of retentive holes was exposed in trimming the casts before reaching the measuring cross section (Figure 3).

Before processing, all retentive holes were sealed with melted wax and then a sheet of base plate wax (Cavex set up regular; Cavex Holland B.V, Haarlem, Netherlands) with 1.5 mm thickness was adapted to the plate of the cast to ensure uniformity of the thickness of the acrylic resin, because it affects distortion[9,10,28]. The tooth arrangement was eliminated because it is practically impossible to arrange all teeth in every 48 cast the same, even with a putty index; therefore, this interventional variable was eliminated from the study, and a wax rim (Bite Wax-Sticks; Azar Teb, Tehran, Iran) was set with a putty index, instead of denture teeth. Each cast was conventionally flasked and heat-processed with Hanau processing machine (Teledyne Hanau; Buffalo, NY). After polymerization, the flasks were allowed to bench cool for 24 hours. For the evaluation of the base adaptation to the cast, back of the casts were trimmed with a dental

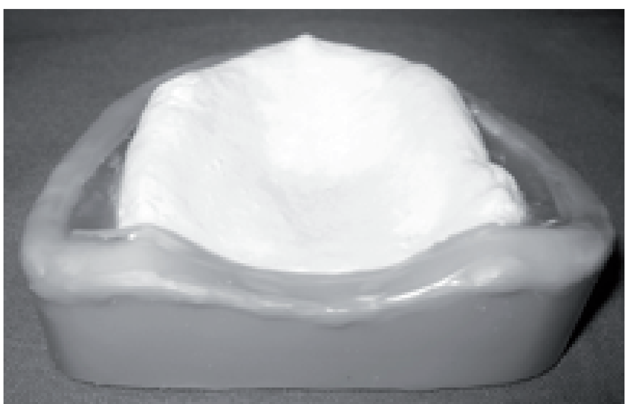

Figure 1. *Sealing vestibules of the master cast with wax*

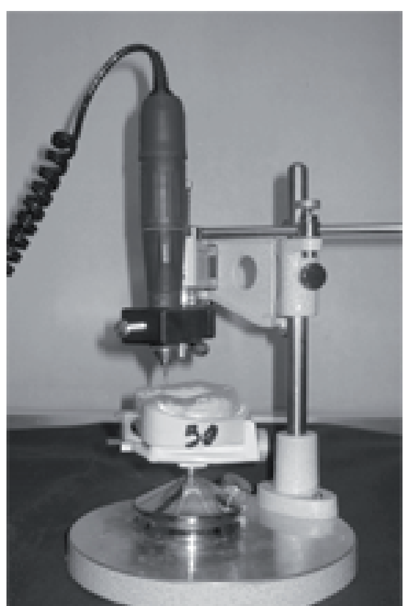

Figure 2. *Handpiece attached to the surveyor*

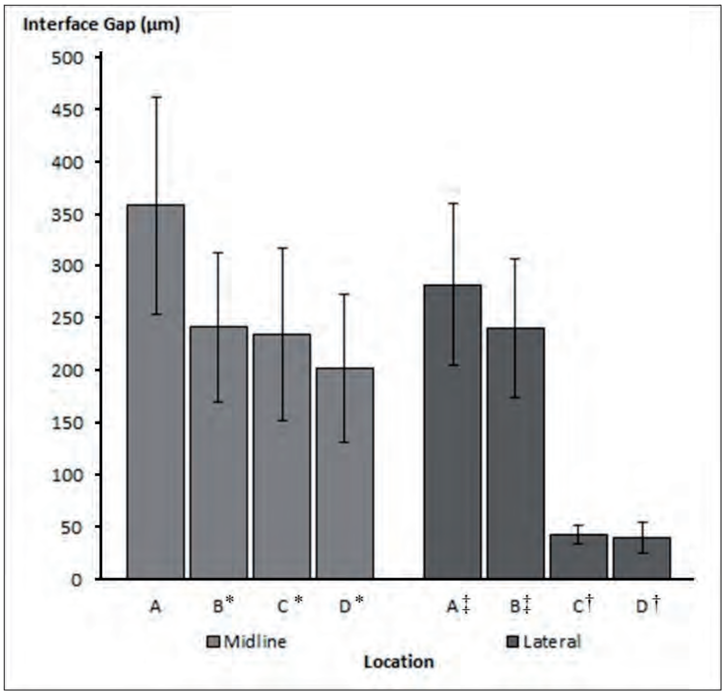

Figure 3. *Mean distance between denture base and master cast in mid palate and lateral palate in four study groups (group A: Control, group B: 1 retentive hole, group C: 3 retentive holes, group D: 5 retentive holes);‡,*,†: Same symbols have no significant difference*

cast trimmer to a reference point which was placed before on the art portion of the cast by an acrylic template. After trimming, the casts and bases were polished with 240- to 600- grit sand papers, then for an accurate measurement the interface area was cleaned of debris with a soft toothbrush, surfactant solution, and pressurized air.

A measuring stereomicroscope (Olympus-SZX9; Tokyo, Japan) with the precision of 10 µm and with the aid of a zooming software (Olysia Zoom Software; Olympus, Tokyo, Japan) was used for the gap measurement across the denture base and interface. After 24 hours of removing the casts from processing unit, measurements were taken. Bias was minimized by a blind evaluation of denture bases, that conventional and anchored denture bases could not be differentiated from each other. X_L is the middle distance between midline and left and right alveolar cusp ridge and for measuring it, the gap between master cast and denture base in left and right of the midline and anterior to the retentive holes were measured for three times and the average of these measurements were considered. X_M is the intersection point of midline and posterior palatal seal area and for measuring it, this gap was measured anterior to the retentive holes which were placed in the midline three times and then the average were considered.

The data were analyzed by SPSS 16 (SPSS for Windows; SPSS Inc., Chicago, IL), using One-way ANOVA test, followed by Post-HOC LSD test.

RESULTS

The mean and standard deviations for the gap distances between denture bases and master casts are given in table 1 for the four test groups (Figure 4). In general, anchoring technique by the means of retentive holes significantly reduced mean gap distances. ANOVA test showed that anchorage technique significantly influences gap distances in lateral and mid-palate areas, in comparison with non-anchorage technique ($p<0.0001$); for X_M, degree of freedom was 3 and F-ratio was 8, and also degree of freedom and F-ratio for X_L are 3 and 74.1, respectively. The post hoc analysis of the interaction of anchoring a location in lateral palate (X_L) showed no significant difference between group A and B ($p=0.056$); however, it showed significant differences in group A comparing to group C and D ($p<0.0001$ for both); furthermore, group B has significant difference with group C and D ($p<0.0001$ for both). However the test did not show any significant differences between group C and D ($p=0.887$). Regarding the interface gap in the mid-palate area, the test only showed significant differences in group A comparing with other groups.

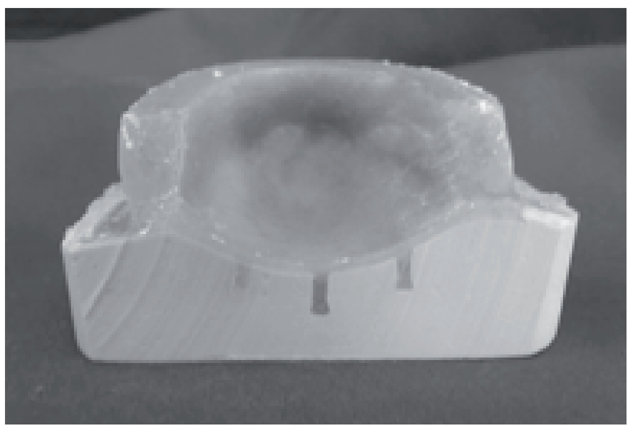

Figure 4. *Cross section of retentive holes after processing*

Table 1. *Mean and standard deviation of the interface gap distances (µm) in four study groups*

Group	Measuring Area	n	Minimum	Maximum	Average	Standard Deviation
A (Control)	X_M	12	291	533	358.5	103.9
	X_L	12	157	403	282.2‡	77.3
B	X_M	12	131	348	241.5*	71.1
	X_L	12	144	336	240.8‡	66.1
C	X_M	12	109	351	234.7*	83.3
	X_L	12	30	57	42.8†	8.9
D	X_M	12	95	305	202.5*	71.3
	X_L	12	19	61	39.8†	14.9

X_M: Intersection point of midline and posterior palatal seal area
X_L: The middle distance between midline and left and right alveolar cusp ridge
‡, *, †: Same symbols have no significant difference

Table 2. *Mean and standard deviation of the interface gap distances (µm) in two study groups (non-anchoraged and anchoraged)*

Group	Measuring area	n	Minimum	Maximum	Average	Standard Deviation
A (non-anchoraged)	X_M	12	219	533	358.5	103.9
	X_L	12	157	403	282.2	77.3
B, C, D (anchoraged)	X_M	36	95	351	226.2	75.3
	X_L	36	19	336	107.8	102.8

Based on the split-plot analysis of variance (ANOVA; α=0.05); in general, anchorage technique significantly decreased the interface gap between denture base and master cast (Table 2, 3), hence it improved the adaptation between them. This test also showed that numbers and locations of retentive holes significantly decrease the interface gap between denture base and master cast.

Table 3. *Split-plot ANOVA*

Variable	Degrees of freedom	F-ratio	P
Anchorage × X_L	1	28.9	0.000
Anchorage × X_M	1	22.8	0.000
Anchorage × Number of holes	2	17.7	0.000

DISCUSSION

There have been different studies evaluating the effect of having denture teeth on the distortion of maxillary denture bases[11,29]. These studies concluded different results which can be due to differences in their methodology. In order to eliminate the effect of the presence of denture teeth on the result, the denture bases were processed without denture teeth.

Based on the results of the present study, gap distance between denture base and master cast decreased with mechanical anchorage in the posterior palatal area. The results of this study were in agreement with the results of Laughlin's study[25]. Anchorage technique in mid palatal, lateral palatal area and vestibules will increase the adaptation, except for the ridge area[25]. The results of Polyzois' study[26] also showed an improvement in adaptation. Based on the results of his study, gap distances at all locations along the posterior border decreased with anchorage technique, and this gap at the lateral palate and mid-palate directly play a crucial role in the integrity of the seal.[26] The improvement in these areas was approximately 61.9% in the lateral palate with the mean decreasing from 282.2 to 107.8 µm, and 36.9% at the mid palatal area from 358.5 to 226.2 µm. According to Laughlin et al, this improvement was about 67% from 0.20 to 0.07 mm in the lateral palate location and 0.31 to 0.10 mm in the mid-palate location. This result could be related to more retentive holes which were applied in that study[25]. Besides the improvement of palatal adaptation, anchoring modifications could decrease other side effects of polymerization shrinkage of denture bases during the processing; e.g. movement of denture teeth and incisal pin opening[30].

The gap distances were in agreement with results from other similar studies by McCartney[17] and Sykora and Sutow.[23] In the present study, the mean gap distance for non-anchored denture bases in midline was 358.5 µm. This was slightly more than Laughlin's study[25] (315 µm) and less than McCartney's study[3] (365 µm), Polyzois' study[26] (466 µm) and Sykora and Sutow's study[23] (378 µm).

The mean gap distance in the lateral palate in conventionally processed dentures (non-anchorage cast) in this study was 282.2 µm. Whereas Laughlin et al.[25] reported a mean gap distance of 204 µm.

The measured interface gaps play an important role in gaining peripheral seal. This study showed that location and numbers of retentive holes have crucial effects on palatal adaptation.

The results of this study clearly demonstrated that the effect of each retentive hole in the palatal adaptation is local, because the interface gap in mid palate showed a significant decrease, in master casts in which retentive holes were in midline (group B). However, in those with three retentive holes in midline and lateral palate (group C), interface gap showed a significant reduction in comparison with group B in lateral palate, and interface gap in mid-palate was the same as in group B.

If the aforementioned theory about localized effect of retentive holes were true, it is expected that two additional retentive holes which were designed in midline and anterior to the posterior palatal area in group D, would not influence the interface gap in the posterior palatal area. The results of the present study agree with this theory. This variable was not analyzed in previous studies, and there is not any research on designing retentive holes anterior to the midline. Comparing control group (group A) with groups B, C & D, showed a significant reduction in the interface gap between denture base and master cast in mid-palate and lateral palate. It is shown that the interface gap between denture base and master cast by the anchorage technique is less affected in the midline than in the lateral palate. This technique is useful for all maxillary dentures and will improve tissue adaptability, retention and tissue response.

Impression technique with selective pressure is used for recovering the loss of adaptation caused by polymerization shrinkage of acrylic resin[25]. Nevertheless, this technique is experimental and it will not lead to an ideal adaptation[31,32].

The advantages of using anchorage technique are conspicuous; this technique improves the adaptability of the maxillary denture base by inter-locking the acrylic resin into the retentive holes and decreasing the distortion of it and will allow dentists to avoid compensative methods. With the anchorage technique, the adaptation in posterior border before separating denture base from cast will improve. In order to avoid polymerization shrinkage in the processing, this technique is more practical than compensative methods[25].

The anchorage technique will improve the stability of denture base and consequently decrease the distortion and other changes caused by polymerization shrinkage, e.g. malocclusion, tooth movement, and opening of the incisal pin. This technique is also easy to apply and it does not need any special instruments; drilling retentive holes is not time-consuming and separating denture bases will not be hard. It only needs trimming before separating denture bases, since these retentive holes are posterior to the PPSA and out of the complete denture tissue surface. Because of the localized effects of retentive holes, in case of shallow or flat palates, the casts should have more retentive holes. It is because of the fact that the tissue surface is more than normal palates and preventing the distortion and adaptation is in more attention[25,33].

CONCLUSION

It is concluded that mechanical anchoring of denture base to master cast leads to a significantly decrease of the distance of these two in lateral and mid-palatal areas. Numbers and locations of retentive holes in this technique also have a localized effect in improving the adaptation of denture bases on master casts.

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