Influence of high expansion dental stone used as investing medium on the changes in occlusal vertical dimension of complete dentures

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Abstract Problem statement: Despite advances in materials and techniques, complete dentures made of acrylic resin experience an increase in the occlusal vertical dimension (OVD) during processing. Many factors that affect the OVD of complete dentures are known. However, no study has examined the effect of using high-expansion dental stone (type V) as an investing material on the OVD.

Purpose: This study investigated the effects of using a high-expansion dental stone as an investing material on changes in the OVD of complete dentures.

Material and methods: Twenty sets of simulated upper and lower dentures were processed by the compression molding technique. Specimens were equally divided into 2 groups. In the dental stone type III (DST III) group, the lower, middle, and upper parts of a flask were filled with DST III. In the dental stone type V (DST V) group, the procedure was the same as in the DST III group, except that the middle layer was made of high-expansion DST V. Changes in the OVD were measured before and after denture processing. Collected data were analyzed with t-test statistics. Differences were considered statistically significant at the 95% confidence level.

Results: Both groups showed a small increase in the OVD as a result of processing, but the OVD increase was significantly less in the DST V group compared to the DST III group.

Conclusion: High-expansion DST V can be recommended as an investing material to reduce the increase in the OVD that may occur while processing complete dentures.

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Introduction

Poly methyl methacrylate (PMMA) or acrylic resin is the most commonly used material for fabricating denture bases (Zarb et al., 2004). It has favorable physical, mechanical, and esthetic properties, and it is easy to manipulate with inexpensive equipment (Arora et al., 2011a). However, this material does not exhibit all of the requirements of an ideal denture base material...
(Zarb et al., 2004; Arora et al., 2011b). In particular, many researchers have shown that PMMA undergoes deformation during polymerization, which is considered to be a major disadvantage of acrylic resin (Chen et al., 1988).

The acrylic resin of complete dentures undergoes thermal expansion during heating, contraction during cooling, and shrinkage during polymerization (Negreiros et al., 2009). These characteristics produce an internal stress that is released during the deflasking step, creating unavoidable dimensional changes and denture base deformation (Becker et al., 1977; Botega et al., 2004; Skinner and Cooper, 1943). In general, heat-polymerized acrylic resin dentures experience a linear shrinkage of 0.3–0.5% during processing, and subsequently show a linear expansion of 0.1–0.2% upon immersion in water. The remaining linear shrinkage equals 0.1–0.4% (Craig, 1993).

During the laboratory processing of complete dentures, an increase in the occlusal vertical dimension (OVD) occurs. The increase in the OVD is an important clinical consideration that is related to essential characteristics of the materials and techniques (Kharat and Fakiha, 1999). Although clinically significant incisal pin opening may occur after processing dentures with this method, the compression molding technique is still considered acceptable (Nogueira et al., 1999). Changes in the vertical dimension of complete dentures must be repaired, necessitating a time-consuming occlusal adjustment (Hayakawa, 1999) that often destroys the anatomy of the artificial teeth (Nogueira et al., 1999).

Several studies have developed investing and processing procedures, aimed to improve the dimensional accuracy and reduce tooth movements (Campos et al., 2005; Consani, 2006; Dukes et al., 1983; Dukes et al., 1985; Strohaver, 1989; Mosharraf et al., 2008). In particular, high-expansion stone casts have been tested to determine their ability to compensate for some of the dimensional changes of the acrylic resin of complete dentures (Arora et al., 2011a; Sykora and Sutow, 1996; Sykora and Sutow, 1997). However, to our knowledge, no study has estimated how using a high-expansion dental stone as an investing medium can influence the OVD of complete dentures. Therefore, the objective of this study was to evaluate how using a high-expansion dental stone to form the middle portion of the mold during the investing procedure would change the OVD of complete dentures. The null hypothesis was that there would be no significant difference in the OVD change of complete dentures fabricated when using an artificial dental stone of type III (DST III) or a high-expansion dental stone of type V (DST V) as the investing medium.

Material and methods

Twenty sets of identical upper and lower stone casts were prepared using a silicone mold (Vertex Castil 21, Vertex Dental, Zeist, The Netherland) of edentulous maxillary and mandibular master casts, without irregularities in the alveolar ridge surfaces. A power analysis (using G*Power Version 3.1.5) was done to determine the required sample size. Casts were made of artificial DST III (Durguix, hard natural stone, Protechno, Girona, Spain). The water:powder ratio was 28 ml:100 g. Record bases were made of auto-polymerizing acrylic resin (Vertex Self Curing, Vertex Dental) on edentulous maxillary and mandibular master casts. Occlusion rims were made using pink baseplate wax (Tenatex Red, Associated Dental Product Ltd., Wiltshire, UK). Master casts were mounted on a semi-adjustable articulator (Dentatus ARL Articulator; AB Dentatus, Hagersten, Sweden), with the Bennett angle at 15° and condylar guide at 30°, before proceeding with the setting of the artificial teeth.

Denture teeth of acrylic resin (MAJOR-DENT, Major Prodotti Dentari S.P.A., Moncalieri, Italy) were arranged in a conventional balanced occlusion. The arrangement of the prosthetic teeth for the interocclusal relationship was anterior vertical overlap and posterior in Angle class I. A wax-up was performed to form the polished surfaces of the upper and low-

Figure 1 Remounting jig.
er dentures. Replicate dentures were reproduced using a silicone matrix. Two sprue holes were prepared in the resulting mold. After the artificial teeth and prepared stone casts were placed in the matrix, the molten pink baseplate wax was poured into the matrix and allowed to cool before removal. All sets of teeth were of the same mold.

The remounting jig was made on the lower part of the articulator, while the master maxillary trial denture was fixed on the upper part, to facilitate the mounting of other sets of trial dentures in the same positions in the articulator (Fig. 1). Sets of trial dentures were mounted on the articulator by using the remounting jig and centric relation records as a guide. Small modifications were needed to complete the occlusion of the denture teeth. The positive contact of the incisal pin with the incisal table was rechecked.

The vertical dimension between reference lines on the upper and lower parts of the articulator was measured by a digital caliper, which can record changes as small as 0.01 mm (Fig. 2). Vertical measurements were made at the wax denture stage (pre-polymerization). Changes in the vertical dimension for each denture were evaluated at a simulated laboratory remount just after denture deflasking (post-polymerization). The difference between the final and initial measurements was referred to as the change in OVD.

The specimens were equally divided into two groups, DST III and DST V, according to investing medium and flasking technique. In the DST III group, artificial DST III was used to fill the lower part of flask (the “drag”); the middle portion of the flask (“cope”), up to the level of the incisal edges of the anterior teeth and the tips of the cusps of the posterior teeth; and the remaining upper portion of the flask (“cap”), as shown in Fig. 3. The procedure in group DST V was the same as in group DST III, except that the second layer (cope) was filled with high-expansion DST V (BK GIULINI GmbH, Ludwigsfen/Rh, Germany), as shown in Fig. 4. The water:powder ratio was 23 ml:100 g. A compression molding technique was used to prepare all dentures. Heat-polymerized acrylic resin (Vertex Regular) was mixed at a polymer:monomer ratio of 3:1 by volume. When the mixture reached a dough consistency, it was placed in the mold over the teeth. A sheet of separating plastic was applied between the gypsum and the acrylic resin.

The flask was closed and submitted to a trial packing procedure. The final closure was at 24.13 N/mm² and maintained for 30 min. The acrylic resin was polymerized in water with a long polymerization cycle. The polymerizing unit (Hanau Engineering Company, Buffalo, NY, USA) was controlled to increase the temperature to 74 °C for 1 h, and then kept at 74 °C for 8 h. After polymerization was completed and the flask was cooled to room temperature inside a water bath, deflasking was carefully completed. Processed dentures attached to casts were returned to their original mountings and secured using plaster of Paris. The vertical dimension between reference lines drawn on the upper and lower parts of the articulator was measured once again.

The Ethics Committee of the Dental Faculty of Damascus University approved the research protocol. Collected data were analyzed with t-test statistics for statistically significant differences at the 95% confidence level.
Results

Both groups showed a small increase in OVD between the upper and lower arms of the articulator, with a mean (±standard deviation) change of 0.721 ± 0.077 in the DST III group and 0.157 ± 0.060 in the DST V group. Vertical measurements made at the wax denture stage and after processing were compared in both groups. The increase in OVD as a result of processing was significant in both groups (DST III: \( t = 29.63, P < .05 \); DST V: \( t = 8.33, P < .05 \), Table 1). The average pin opening was compared between the groups with a separate variance independent \( t \)-test. The increase in OVD was significantly less in the DST V group compared to the DST III group (\( t = 18.32, P < .05 \)) (Table 2).

Discussion

In accordance with the results of the present research, the stated null hypothesis was rejected. The use of high-expansion DST V as an investing material for fabricating the middle portion of the mold may aid in reducing the OVD increase of complete dentures that results from the polymerization process.

The properties of acrylic resin of complete dentures have been improved, but undesirable shrinkage is still a problem (Turakhia and Ram, 2005; Baydas et al., 2003; Wong et al., 1999). A comparison of the changes in the OVD is an important method for estimating new denture base materials and processing techniques (Barbosa et al., 2002). Several studies have reported that the incisal pin can rise from the incisal table after dentures are processed by using dental stone investing medium and the compression molding technique (Kharat and Fakiha, 1999; Nogueira et al., 1999; Dukes et al., 1983; Dukes et al., 1985; Strohaver, 1989; Nelson et al., 1991). However, studies by Mosharraf et al. (2008); Barbosa et al. (2002), Keenan et al. (2003), and Swords et al. (2000) reported an increase of the OVD of a single denture, rather than the overall pin opening on both the maxillary and mandibular complete dentures. The OVD increase could have been due to movement of the upper and lower posterior teeth during processing. Therefore, measuring an increase in the OVD of a single denture is not a particularly accurate method.

This study aimed to reduce the amount of incisal pin opening by using high-expansion dental stone to make the cope of the mold. Twenty sets of simulated upper and lower wax dentures were prepared, to preclude variations in polymerization changes that may result from differences in shape and size (Strohaver, 1989). Changes in the OVD were measured by using a digital caliper, according to a previously described method (Barbosa et al., 2002; Mosharraf et al., 2008; Swords et al., 2000).

Heat-activated resin suffers from two kinds of shrinkage during polymerization. When it is mixed, the density of the mass changes, resulting in polymerization-related shrinkage (Anusavice and Phillips, 2003; Skinner and Cooper, 1943). In the early stages of the cooling process, heat-activated resin remains relatively soft. It undergoes contraction at approximately the same rate as the surrounding investing material (Anusavice and Phillips, 2003). When cooled below the glass transition temperature of the resin, the mass of resin exhibits thermal shrinkage, which occurs at a rate different from that of the surrounding investing material (Anusavice and Phillips, 2003). Thus, the type of investing medium selected is an important factor that may affect the overall dimensional changes of processed denture bases.

### Table 1

<table>
<thead>
<tr>
<th>Investing method</th>
<th>Paired Differences</th>
<th>( t )</th>
<th>( df )</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group DST III</td>
<td>Postpolymerization–prepolymerization</td>
<td>0.72100</td>
<td>0.07695</td>
<td>29.630</td>
</tr>
<tr>
<td>Group DST V</td>
<td>Postpolymerization–prepolymerization</td>
<td>0.15700</td>
<td>0.05964</td>
<td>8.325</td>
</tr>
</tbody>
</table>

* Statistically significant (\( P < 0.05 \)).

### Table 2

<table>
<thead>
<tr>
<th>Change in OVD</th>
<th>Levene’s test for equality of variances</th>
<th>( t )-Test for equality of means</th>
<th>95% Confidence interval of the difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( F ), Sig. ( t ), ( df ) ( F ), Sig. (2-tailed) ( Mean ) differences ( Std. error ) difference Lower Upper</td>
<td>( Mean ) differences ( Std. error ) difference Lower Upper</td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>Equal variances not assumed</td>
<td>0.874, 0.362, 18.320, 18</td>
<td>0.000*</td>
</tr>
</tbody>
</table>

* Statistically significant (\( P < 0.05 \)).
In the current study, the two investing methods produced a small increase in the vertical measurements after the processing of the simulated complete dentures (group DST III: 0.721 ± 0.077; group DST V: 0.157 ± 0.060). Although small, the differences were statistically significant. These results are comparable to those of previous studies that showed an increase in the OVD of complete dentures as a result of processing (Kharat and Fakih, 1999; Nogueira et al., 1999; Campos et al., 2005; Dukes et al., 1985; Strohaver, 1989; Barbosa et al., 2002; Nelson et al., 1991; Basso et al., 2006). The mean increase in OVD in the DST III group was greater than those found by Strohaver (1989) (0.63 mm) and Wesley et al. (1973) (0.56 mm), but less than those found by Nogueira et al. (1999) (1.16 mm), Basso et al. (2006) (0.872 mm), and Dukes et al. (1983) (0.76 mm). The mean increase in OVD for the DST V group was less than those found by all previous studies. Differing results among these studies may be attributed to differences in the forms and sizes of the casts, acrylic resin used, and number of trial packing(s) (Basso et al., 2006).

Comparisons between dentures fabricated by using DST V or DST III showed that the increase in OVD was significantly less in the DST V group. This difference may be explained by the differences in the water content of the two investing materials. Teraoka and Takahashi (2000) stated that a reduction in the amount of free water in the gypsum mold plays an important role in the fabrication of well-fitting dentures. High-expansion DST V, which contains less water than DST III, probably contributes to provide more accurate denture fitting with a smaller incisal pin opening. The compressive strength of gypsum products is conversely related to the water:powder ratio of the mix. Consequently, DST V shows a higher compressive strength than DST III (Anusavice and Phillips, 2003). With its higher strength, DST V may restrict the artificial teeth and contribute to reduce the increase in the OVD of complete dentures that results from polymerization.

Although the increases in OVD with both investing methods were <1 mm and, in accordance with Nelson et al. (1991), these changes are considered technically acceptable, complete dentures made by using DST V as an investing medium may be easier to adjust after processing because of the smaller increase in the OVD. The use of DST V as an investing medium may reduce the occlusal adjustment time and size of modifications in the laboratory.

The present in vitro study has some limitations. First, changes in the OVD during denture construction are affected by several factors. However, in this study, changes were evaluated when DST V was used to make only the middle portion of the gypsum mold. The findings suggest that the investing medium has an effect on changes in the OVD of complete dentures occurring during denture construction. Further research is needed to understand the effects of investing materials and techniques on the mechanism of changes in the OVD of complete dentures.

Conclusions

Within the limitation of the current investigation, it could be concluded that using high-expansion DST V as an investing material for fabricating the middle portion of the mold may aid in reducing the increase in the OVD of complete dentures that results from the polymerization process.

Conflict of interest

The current research is free of conflict of interest.

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References


