Dimensional accuracy of stone casts made by a monophase impression technique using different elastomeric impression materials

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Abstract

Impression taking is a critical step in the process of producing successful crowns and fixed partial dentures in oral rehabilitation, and the impression material is an important factor related to clinical success. **Aim:** The aim of this in vitro study was to assess and compare the dimensional accuracy of stone casts made from a monophase technique using 10 elastomeric impression materials. **Methods:** First, a stainless steel model with reference points in the teeth 33, 43, 37, and 47 was used to obtain the impressions. The distances were measured among teeth 33-43, 37-47, 33-37, and 43-47. For the impression technique, acrylic resin trays were made with an internal relief of approximately 2 mm. Specific adhesives for each material were used in the custom trays. Tray detachment movement was standardized by pneumatic equipment. After the impression procedures and obtaining of samples, the stone casts were observed in a measuring microscope at 30x magnification. Data recorded for each distance were analyzed statistically by one-way analysis of variance and Tukey's test at 5% significance level. **Results:** Stone casts made with elastomeric impression materials showed statistically significant (p<0.05) differences when the dimensional accuracy values were compared. The order for the highest to lowest accuracy for the types of impression materials was as follows: polyvinylsiloxane (PVS), polyether, polysulfide and polydimethylsiloxane (PDMS). **Conclusions:** PVS were the most dimensionally accurate impression materials, and the PDMS showed the worst results of dimensional accuracy.

Keywords: impression technique, dimensional accuracy, dental materials.

Introduction

High accuracy impression materials (elastomeric impression materials) appeared in dentistry in the 1950s1-2. Nowadays, four different elastomeric impression materials are used namely polysulfide, polyether, polydimethylsiloxane (PDMS) and polyvinylsiloxane (PVS), and each one of them has specific chemical reactions and setting characteristics. The elastomeric impression materials made with a silicone base are found in four different viscosities: putty (type 0), heavy-body (type 1), regular or medium-body (type 2) and light-body (type 3). Polyether and polysulfide are already available in all consistencies, except putty1-6. The elastomeric impression materials possess elastic behavior after the set reaction; in other words, they resemble an rubber7-8. These materials are polymers...
formed by large molecular chains. When tension is applied, these chains are uncoiled, elastically recovering after the load removal\(^1,6\). Impression materials should reproduce hard and soft tissues in order to obtain biologically, mechanically, functionally and esthetically acceptable restorations\(^9-10\). However, dimensional changes in the molds inherent to the impression materials can occur, such as: wettability, handling properties\(^11\), viscosity and thickness of the material existing between the oral structures and tray, fixation method of impression material to tray\(^12-13\), time elapsed for cast pouring\(^13\), material’s hydrophilicity\(^11\), byproduct loss, polymerization shrinkage, thermal shrinkage due the temperature change (from the mouth to room temperature), incomplete elastic recovery, and, in some cases, soak\(^1\). Other factors, such as tray selection, impression technique and preparation design can also influence the impression quality\(^14\).

There are several brand names and categories of impression materials that can be used in dentistry. Dimensional stability of impression materials has been widely discussed in the dental literature\(^10,15\), revealing significant differences in the properties of products of the same type. Some dentists still finds unclear which category of impression materials is best for clinical uses to obtain success of prosthodontic procedures\(^10\). The use of an appropriate impression material can reduce considerably the likelihood of inaccuracies in the molds\(^7\). New materials have been developed and subjected to continuous modifications with the aim of improving the impression quality, but these modifications do not guarantee maintenance of their properties\(^16\). Then, it is important to evaluate the dimensional accuracy of recently developed materials.

The aim of this in vitro study was to evaluate the dimensional accuracy of stone casts made with different elastomeric impression materials by a monophase impression technique. The hypothesis tested in the present study was that there are differences on dimensional accuracy in stone casts among the elastomeric impression materials.

**Material and methods**

Table 1 shows the materials used in the study.

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**Table 1 - Materials (brand names) used and manufacturers.**

<table>
<thead>
<tr>
<th>Brand names</th>
<th>Manufacturers</th>
<th>Batch Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clonage (PDMS)</td>
<td>DFL, Rio de Janeiro, RJ, Brazil</td>
<td>08010000</td>
</tr>
<tr>
<td>Oranwash L (PDMS)</td>
<td>Zhermack, Rovigo, Italy</td>
<td>107165</td>
</tr>
<tr>
<td>Xantopren VL Plus (PDMS)</td>
<td>Heraeus Kulzer GmbH, Hanau, Germany</td>
<td>R330335</td>
</tr>
<tr>
<td>Silon 2 APS (PDMS)</td>
<td>Dentsply Ind. e Com. Ltda., Petrópolis, RJ, Brazil</td>
<td>349629</td>
</tr>
<tr>
<td>Futura AD (PVS)</td>
<td>DFL, Rio de Janeiro, RJ, Brazil</td>
<td>462216</td>
</tr>
<tr>
<td>Express Regular Set (PVS)</td>
<td>3M Unitek, Monrovia, CA, USA</td>
<td>387100</td>
</tr>
<tr>
<td>Elite HD+ Normal Setting (PVS)</td>
<td>Zhermack, Rovigo, Italy</td>
<td>110577</td>
</tr>
<tr>
<td>Aquasil Ultra Regular Set (PVS)</td>
<td>Dentsply GmbH, Konstanz, Germany</td>
<td>0811003044</td>
</tr>
<tr>
<td>Impregum Soft (Polyether)</td>
<td>3M Unitek, Monrovia, CA, USA</td>
<td>1026300114</td>
</tr>
<tr>
<td>Permlastic (Polysulfide)</td>
<td>Kerr Corporation, Romulus, MI, USA</td>
<td>0-1088</td>
</tr>
<tr>
<td>Rubber Base Adhesive</td>
<td>Kerr Corporation, Romulus, MI, USA</td>
<td>8-1099</td>
</tr>
<tr>
<td>Polyether Adhesive</td>
<td>3M Unitek, Monrovia, CA, USA</td>
<td>0003061</td>
</tr>
<tr>
<td>Universal Adhesive</td>
<td>Heraeus Kulzer GmbH, Hanau, Germany</td>
<td>280023</td>
</tr>
</tbody>
</table>

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**Stainless steel model evaluation**

At first, a stainless steel model of the mandibular arch partially edentulous with reference points in the teeth 37, 47, 33, and 43 was made\(^17\). The transversal distances among teeth 33-43 and 37-47, and anteroposterior among teeth 33-37 and 43-47 (Figure 1), were measured by a measuring microscope at 30x magnification (Olympus\(^*\) Measuring Microscope STM, Olympus Optical Co., Japan).

**Fig. 1. Distances considered in the measurements.**

**Monophase impression technique**

All elastomeric impression materials were handled following the manufacturers’ instructions, and impressions procedures were made in a room with temperature and relative humidity controlled (23°C ± 2°C and 50% ± 10%)\(^2,4,18\).

Custom acrylic resin trays (Vipi Flash, VIPI, Pirassununga, SP, Brazil) were made with an internal relief of approximately 2 mm\(^18-19\) to provide an adequate and standard thickness to the impression material\(^20-21\). A 2-mm-thick polypropylene spacer was used on the stainless steel model. Then, the acrylic resin was placed on the set polypropylene...
spacer/model to obtain the custom trays with 2 mm of relief. Initially, an adhesive layer was applied to each elastomeric impression material, throughout the internal surface of all trays, which left on a bench for 5 min for adhesive drying\textsuperscript{18,22}. Afterwards, the light-body elastomeric impression materials were handled following the manufacturer’s instructions and used to cover the whole internal surface of the tray, being careful with possible excesses.

The set tray/impression material was positioned and seated manually on the stainless steel model, from posterior to anterior. After the setting time recommended by the manufacturer, the tray was attached to the pneumatic equipment and detached from stainless steel model by a movement standardized, in order to avoid distortions in the mold (Figure 2)\textsuperscript{18} due to material expansion that occur by tension release after the impression removal\textsuperscript{20}. The detachment pressure was 3 bar. This procedure was repeated five times for each impression material brand name (n=5).

Following the manufacturers’ instructions, a ratio of 150 g of dental stone type IV (Durone IV, Dentsply, São Paulo, SP, Brazil) and 28.5 mL of water was used. Each of five elastomeric casts was poured after 30 min of the tray removal, in order to allow a correct elastic recovery. In the same way as in the stainless steel model evaluation, three measurements were made by a single calibrated operator in each one of the four distances among the teeth (33-43, 33-37, 43-47, and 37-47), and the respective means were recorded.

![Fig. 2. Mold removal with single movement. After setting of the impression material, the tray was attached to the pneumatic equipment and the device actuated. Then, the tray was detached from the stainless steel model by upright movement.](image)

**Statistical analysis**

Data recorded for each distance were analyzed statistically by one-way analysis of variance and Tukey’s test at 5% significance level.

**Results**

Tables 2 and 3 show that there was a significant difference in the dimensional change means when the impression materials were compared for all distances: 33-43, 33-37, 43-47, and 37-47. Each one of the four distances among the teeth (33-43, 33-37, 43-47, and 37-47), and the respective means were recorded.

**Table 2 - Dimensional change means and SD (%) of stone casts made with the elastomeric impression materials (transversal distances).**

<table>
<thead>
<tr>
<th>Distance</th>
<th>Silon 2 APS</th>
<th>Clonage</th>
<th>Permlastic</th>
<th>Xantopren VL</th>
<th>Oranwash L</th>
<th>Impregum</th>
<th>Futura AD</th>
<th>Elite HD+</th>
<th>Aquasil Ultra</th>
<th>Express</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-47 distance</td>
<td>-0.29 (0.02) a</td>
<td>-0.20 (0.02) b</td>
<td>-0.19 (0.03) bc</td>
<td>-0.17 (0.01) bcd</td>
<td>-0.15 (0.01) cd</td>
<td>-0.13 (0.01) d</td>
<td>-0.04 (0.01) e</td>
<td>-0.03 (0.01) e</td>
<td>-0.03 (0.01) e</td>
<td>-0.01 (0.01) f</td>
</tr>
<tr>
<td>33-43 distance</td>
<td>-0.33 (0.02) a</td>
<td>-0.23 (0.02) ab</td>
<td>-0.21 (0.03) b</td>
<td>-0.20 (0.03) b</td>
<td>-0.19 (0.02) b</td>
<td>-0.17 (0.02) b</td>
<td>-0.06 (0.02) c</td>
<td>-0.06 (0.02) c</td>
<td>-0.05 (0.02) cd</td>
<td>-0.02 (0.01) d</td>
</tr>
</tbody>
</table>

Means followed by different lowercase letters differ significantly (p<0.05)

**Table 3 - Dimensional change means and SD (%) of stone casts made with the elastomeric impression materials (anteroposterior distances).**

<table>
<thead>
<tr>
<th>Distance</th>
<th>Silon 2 APS</th>
<th>Clonage</th>
<th>Permlastic</th>
<th>Xantopren VL</th>
<th>Oranwash L</th>
<th>Impregum</th>
<th>Futura AD</th>
<th>Elite HD+</th>
<th>Aquasil Ultra</th>
<th>Express</th>
</tr>
</thead>
<tbody>
<tr>
<td>33-37 distance</td>
<td>-0.43 (0.02) a</td>
<td>-0.42 (0.03) a</td>
<td>-0.38 (0.01) ab</td>
<td>-0.37 (0.02) ab</td>
<td>-0.30 (0.01) bc</td>
<td>-0.24 (0.02) cd</td>
<td>-0.19 (0.02) de</td>
<td>-0.18 (0.03) de</td>
<td>-0.17 (0.01) de</td>
<td>-0.13 (0.02) e</td>
</tr>
<tr>
<td>43-47 distance</td>
<td>-0.45 (0.03) a</td>
<td>-0.44 (0.03) a</td>
<td>-0.40 (0.02) ab</td>
<td>-0.39 (0.03) ab</td>
<td>-0.32 (0.02) bc</td>
<td>-0.26 (0.02) cd</td>
<td>-0.25 (0.02) cd</td>
<td>-0.24 (0.04) cd</td>
<td>-0.22 (0.02) d</td>
<td>-0.18 (0.02) d</td>
</tr>
</tbody>
</table>

Means followed by different lowercase letters differ significantly (p<0.05)

(p<0.0001), 33-37 (p<0.0001), 43-47 (p<0.0001) and 37-47. In general, the PVS showed the best results, followed by polyether. On other hand, polysulfide and PDMS had the worst results. The stone casts made with Express presented the smallest dimensional change means among all impression materials. Silon 2 APS and Clonage produced casts with the largest dimensional change means.

**Discussion**

The hypothesis tested in the present study was accepted, as the results showed that, in general, PVS provided greater accuracy in the stone casts and greater reliability in impression structures than polysulfide, polyether and PDMS. These results can be attributed to the excellent physical and mechanical properties of this type of material, such as good dimensional stability and elastic recovery (approximately 99%)\textsuperscript{10}, in addition to an appropriate tear strength\textsuperscript{7}. PVS materials possess a set reaction by the terminal group ethylene or vinyl with hydride groups\textsuperscript{3-2}, without the formation of by-products and with non-occurring impression material shrinkage, allowing that these materials stay dimensionally stable after impression removal\textsuperscript{12,13}.

In general, PVS materials showed results that did not differ significantly among themselves. The small differences found in the dimensional accuracy among the PVS materials
can be attributed to the variability in the composition of each brand name, mainly in the matrix-filler ratio, which can provide the material with different levels of shrinkage polymerization and elastic recovery.\textsuperscript{4,24}

The stone casts made with the polyether material behaved, statistically, in the same manner as stone casts made from PVS in the anteroposterior measures (43-47 and 33-37) and as the PDMS Oranwash L (Zhermack, Rovigo, Italy) and Xantopren VL (Heraeus Kulzer GmbH, Hanau, Germany) in the distance 37-47. For the other transversal distance, 33-43, the polyether did not differ among Oranwash L, Xantopren VL, and Permlastic (Kerr Corporation, Michigan). These results differ from those found results in other studies.\textsuperscript{7,25} In which polyether presented better dimensional accuracy than condensation silicone-based materials and polysulfide. However, these results corroborate those of another study\textsuperscript{9} in which polyether had an intermediate behavior between PDMS and PVS. A possible explanation for these conflicting results is that the behavior of this material is easily influenced by the room humidity as this material has a hydrophilic nature.\textsuperscript{1,6}

In laboratorial studies, the material stays in a dry room and does not absorb water from the room. It is speculated that, under clinical conditions, water sorption could compensate partly for the shrinkage observed in the laboratorial tests, as seen in this study. Besides, the polyether has inferior tear strength than PVS, so this may avoid its indication for use in interproximal and subgingival prepared tooth areas.\textsuperscript{26}

PDMS materials, specifically Silon 2 APS and Clonage, were the materials that created stone casts with the highest dimensional change values, as found in other studies.\textsuperscript{26-27} The worst performance for that material class is due to the continuous polymerization that occur after setting of the impression material and is more accentuated than in other materials, which causes the evaporation of volatile byproducts, such as ethyl alcohol, and affects the dimensional stability and the accuracy of the PDMS.\textsuperscript{1,26,28}

Polysulfide polymerization occurs by the condensation reaction between the lead oxide and the pending and terminal groups with the mercaptan groups.\textsuperscript{5,6} In that reaction, as in PDMS polymerization, there is byproduct formation (water), which can evaporate and distort the mold. Therefore, polysulfide had similar behavior to that of PDMS. Furthermore, the elastic recovery of this material is smaller and more incomplete than in other elastomeric materials.\textsuperscript{5} Other factors, such as short handling time, prolongable time of polymerization, high sensitivity to temperature and humidity and higher tear strength can affect the dimensional accuracy.\textsuperscript{26}

The ISO 4823 specification admits that dimensional changes less than 1.5% to elastomeric impression materials are clinically acceptable. Within the limitations of this study, despite the statistical differences found among the elastomeric impression materials, when poured in 30 min after impressions in a room with temperature and relative humidity controlled, all the stone casts made with those impression materials showed satisfactory dimensional accuracy. Future studies are needed to verify the use of the elastomeric impression materials with others impression techniques and the clinical relevance. The choice of a product for a particular clinical application should be based on material’s properties rather than on the type and class of impression material. The dental professionals should be informed about the advantages and disadvantages of each material to adequately use them in clinical practice and provide adequate clinical longevity to the prostheses.

Acknowledgements

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References