

# Dimensional Accuracy of Stone Casts Made from Silicone-Based Impression Materials and Three Impression Techniques

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The aim of this study was to measure and compare the dimensional accuracy of stone casts of a partially edentulous mandibular arch made by two condensation silicones, two addition silicones and three impression techniques (1-step putty/light-body, 2-step putty/light-body and monophasic technique). A partially edentulous standard stainless steel mandibular arch cast was obtained with reference points on the permanent mandibular right and left canines, and permanent mandibular right and left second molars. The anteroposterior distances (between the mandibular left canine and second molar and between the mandibular right canine and second molar) and transverse distances (between the mandibular left and right canines and between the mandibular left and right second molars) of stainless steel cast were measured by a microscope at 30× magnification and 0.5 μm accuracy. All impressions were made with condensation or addition silicones. The 1- and 2-step putty/light-body impressions were accomplished with putty and light-body materials and the monophasic impressions with light-body material only. After the impression procedures, accuracy of each material and technique was assessed measuring the stone casts poured (n=5) from the impressions, by the same microscope. The differences between the values of stone cast and stainless steel cast were calculated, presented as percentages and analyzed statistically by two-way ANOVA and the means compared by Tukey's test ( $\alpha=0.05$ ). All distances measured on stone casts showed altered dimensions with significantly negative linear changes (shrinkage) as compared to those of the stainless steel cast. The stone casts made from the addition silicones were dimensionally more accurate. No differences were found among the impression techniques.

**Key Words:** silicone elastomers, dental impression technique, dental impression materials, dimensional accuracy.

## Introduction

Several critical procedures must be followed to obtain the mold and to make accurate dental stone casts (1-3). Among them is the correct choice and use of impression techniques (2,3-6) as well as impression materials (4). Over the years, a lot of materials and impression techniques were developed to achieve perfect detail reproduction of the oral environment. The first high accuracy impression material, elastomeric impression material, was used for dental purposes in the 1950s (1,7). Silicone-based impression materials are elastomeric impression materials used in dental practice. The polymerization of these materials occurs by condensation (polydimethylsiloxanes - PDMS) or by addition (polyvinyl siloxanes - PVS) reactions (2,4,7).

The silicones for oral impressions are widely used in dentistry because they have high accuracy and dimensional stability (7-10). Furthermore, these materials have excellent elastic recovery, minimum permanent distortion and good tear strength (7,8). The silicone-based materials are commercially available in different viscosities (11), allowing them to be used in several impression techniques

adequate to improve the molds accuracy, such as 1-step putty/light-body technique, 2-step putty/light-body technique and the monophasic technique (6,12-14).

Regarding the dimensional accuracy, a recent study showed that almost 90% of molds presented one or more observable errors, requiring a more critical mold analysis by dental practitioners (15). There are several factors that may affect the dimensional accuracy of elastomeric impression material molds, including the type of the used material viscosity (4,5,16-18), thickness (16,17), the impression technique (3,4,6,17), the adhesion method of impression materials to the tray, time elapsed to cast pouring (17), the material's hydrophilicity, release of byproducts, polymerization shrinkage, thermal shrinkage and incomplete elastic recovery (15-18).

There are several discussions in the dental literature about the effect of material and impression technique on the cast accuracy and prosthesis fitting. Some authors showed that the cast accuracy is affected more by the used impression technique than by the chosen material (5,6,18-20). Other researchers reported that the impression

technique does not affect the dimensional accuracy (3,8,14,21,22). Furthermore, some studies showed better dimensional accuracy when an individual acrylic resin tray is used (16). Thus, the aim of this study was to measure and to evaluate the dimensional accuracy of casts made by three impression techniques (1-step putty/light-body, 2-step putty/light-body and monophasic) using addition and condensation silicones. The hypotheses were that (1) the addition silicones provide more accurate stone casts than condensation silicones and (2) no differences exist in the dimensional accuracy among the impression techniques.

## Material and Methods

Table 1 displays the materials used in the study. All elastomeric impression materials were used in the putty (type 0) and light-body (type III) viscosities. A partially edentulous stainless steel mandibular arch cast was fabricated with reference points (23) on the permanent

mandibular left and right canines, and permanent mandibular left and right second molars. The transverse distances between the permanent mandibular left and right canines (distance 1) and between the mandibular left and right second molars (distance 2) and the anteroposterior distances between the mandibular right canine and right second molar (distance 3) and the mandibular left canine and left second molar (distance 4) were measured using a microscope at 30× magnification (Measuring Microscope STM; Olympus Optical Co., Tokyo, Japan) (Fig. 1). Handling was performed according the manufacturers' instructions and impressions were made under controlled temperature and relative humidity ( $23\pm 2$  °C and  $50\pm 10\%$ ) (10).

For the 1-step putty/light-body technique, the putty

Table 1. Materials used

Trade names	Manufacturers
Zetaplus (PDMS)	Zhemarck, Rovigo, Italy
Oranwash L (PDMS)	Zhemarck, Rovigo, Italy
Xantopren VL Plus (PDMS)	Heraeus Kulzer GmBH, Hanau, Germany
Optosil Comfort (PDMS)	Heraeus Kulzer GmBH, Hanau, Germany
Express Regular Set (PVS)	3M Dental Products, CA, USA
Aquasil Ultra Regular Set (PVS)	Dentsply Ind. e Com. Ltda, Petrópolis, RJ, Brazil

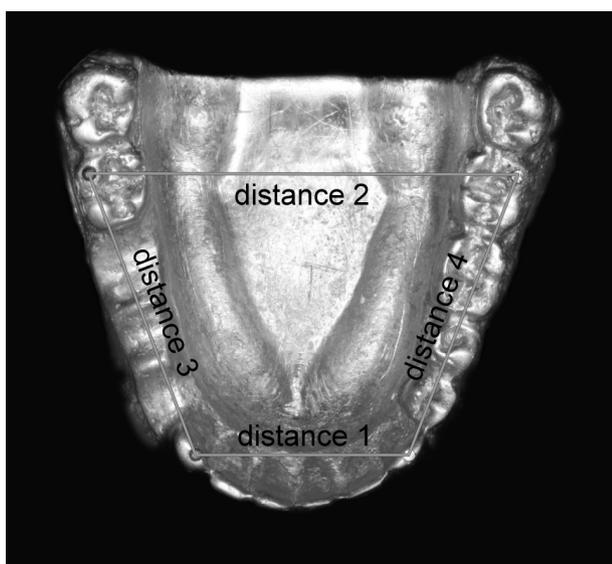


Figure 1. Stainless steel cast and the distances measured in the study.

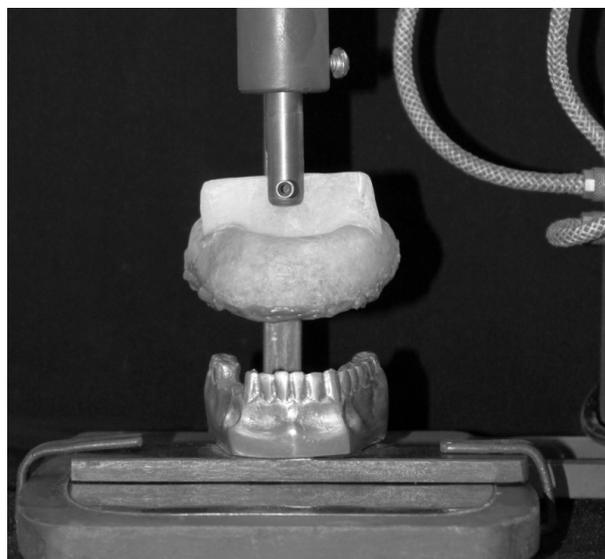


Figure 2. Detachment tray/cast using an individual acrylic resin tray.

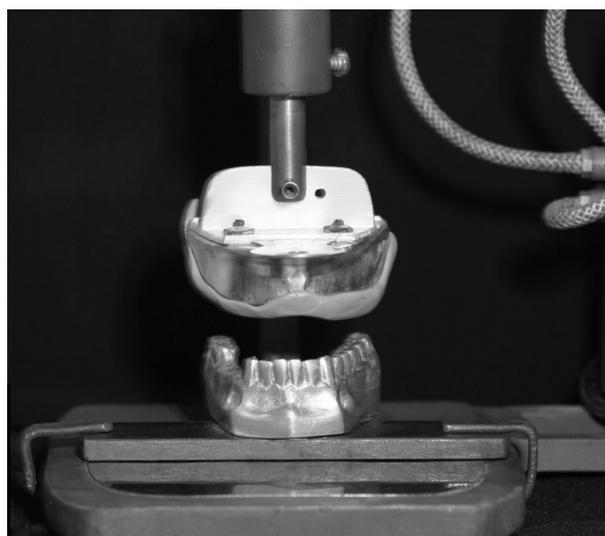


Figure 3. Detachment tray/cast using a metallic stock tray.

and light-body material were handled together. The impressions were made using metallic stock trays I-3 (Tecnodont, Casalecchio di Reno, Italy). The elastomeric impression material of putty viscosity was handled using plastic gloves to avoid the inhibition of polymerization reaction by contaminants of the latex gloves.

With the 2-step putty/light-body technique was used a polypropylene spacer 2 mm thick on the stainless steel cast to form a space (relief). Thus, a first impression was made using a metallic stock I-3 tray with putty material. A first mold was produced using this impression. Then, the spacer was removed and the light-body material handled and placed over the putty material, and the tray replaced on the stainless steel cast to accomplish the final impression.

The monophasic technique was accomplished in a single-step procedure with light-body viscosity only. Individual acrylic resin trays (Vipi Flash; VIPI, Pirassununga, SP, Brazil) with internal 2 mm relief (24) were manufactured. A layer of universal adhesive (Heraeus Kulzer GmbH, Hanau, Germany) was applied inside each tray. The drying time for the adhesive was 5 min. After handling, the elastomeric impression material was placed to cover the tray's internal surface, allowing a homogeneous distribution of the material.

For all impression techniques, the group tray/impression material was positioned and seated on the stainless steel cast from posterior to anterior direction and the tray detachment movement was standardized by a pneumatic equipment in order to avoid distortions in the mold (22,24) (Figs. 2 and 3).

Dental stone type IV (Durone; Dentsply, Petrópolis, RJ, Brazil) was used in a water/powder ratio of 28.5 mL/150 g for stone cast pouring. The casts were poured after a period of 30 min, to allow the correct elastic recovery of impression materials. Five samples were produced for each material and impression technique. As in the stainless steel cast, for each distance among the teeth, three readings were made by a single calibrated operator and the means were calculated.

The means were recorded and compared with the original means obtained from the stainless steel cast. The differences between the values of stone cast and stainless steel cast were calculated and presented as percentages. If negative, the data indicated that there was decrease of the distances (shrinkage); if positive, it indicated volume increase (expansion). Data were analyzed statistically by two-way analysis of variance and Tukey's test at a 5% significance level.

## Results

Tables 2-5 present the percentages of dimensional alteration for each distance, according to the impression materials and techniques. All materials showed shrinkage. The condensation silicones had the highest values of dimensional alteration. No significant difference was found ( $p>0.05$ ) among the addition silicones, except for

Table 2. Mean dimensions and standard deviations (%) of stone casts for distance 1

Material/Technique	2-step	1-step	Monophase
Optosil/Xantopren	-0.20±0.02 a, A	-0.20±0.04 a, A	-0.20±0.03 a, A
Zetaplus/Oranwash	-0.19±0.01 a, A	-0.19±0.02 a, A	-0.19±0.02 a, A
Aquasil	-0.04±0.01 b, A	-0.05±0.01 b, A	-0.05±0.02 b, A
Express	-0.02±0.02 b, A	-0.02±0.01 b, A	-0.02±0.01 b, A

Means followed by different lowercase letters in columns and uppercase letters in rows are statistically different at 5% by Tukey's test.

Table 3. Mean dimensions and SD (%) of stone casts for distance 2

Material/Technique	2-step	1-step	Monophase
Optosil/Xantopren	-0.17±0.01 a, A	-0.17±0.01 a, A	-0.17±0.01 a, A
Zetaplus/Oranwash	-0.15±0.01 a, A	-0.16±0.02 a, A	-0.15±0.01 a, A
Aquasil	-0.03±0.01 b, A	-0.03±0.01 b, A	-0.03±0.01 b, A
Express	-0.01±0.01 c, A	-0.01±0.01 c, A	-0.01±0.01 c, A

Means followed by different lowercase letters in columns and uppercase letters in rows are statistically different at 5% by Tukey's test.

Table 4. Mean dimensions and SD (%) of stone casts for distance 3

Material/Technique	2-step	1-step	Monophase
Zetaplus/Oranwash	-0.40±0.02 a, A	-0.42±0.01 a, A	-0.40±0.02 a, A
Optosil/Xantopren	-0.39±0.02 a, A	-0.40±0.02 a, A	-0.39±0.03 a, A
Aquasil	-0.21±0.01 b, A	-0.23±0.02 b, A	-0.22±0.02 b, A
Express	-0.18±0.02 b, A	-0.18±0.03 b, A	-0.18±0.01 b, A

Means followed by different lowercase letters in columns and uppercase letters in rows are statistically different at 5% by Tukey's test.

Table 5. Mean dimensions and SD (%) of stone casts for distance 4.

Material/Technique	2-step	1-step	Monophase
Zetaplus/Oranwash	-0.37±0.02 a, A	-0.40±0.04 a, A	-0.37±0.01 a, A
Optosil/Xantopren	-0.37±0.01 a, A	-0.38±0.02 a, A	-0.37±0.02 a, A
Aquasil	-0.16±0.03 b, A	-0.16±0.01 b, A	-0.16±0.02 b, A
Express	-0.13±0.02 b, A	-0.13±0.01 b, A	-0.13±0.01 b, A

Means followed by different lowercase letters in columns and uppercase letters in rows are statistically different at 5% by Tukey's test.

the distance 2 where Express showed more dimensional accuracy than Aquasil in all impression techniques. No significant difference was found ( $p>0.05$ ) among the impression techniques.

## Discussion

The impression procedure must reproduce accurately the oral structure details to allow the manufacturing of accurate stone casts (1). Dentures for patient oral rehabilitation will be fabricated on these casts. The fit accuracy of a denture is a key factor to long-term prosthetic treatment success and therefore to avoid misfit, all clinical and laboratory procedures must be followed (1,2).

In all studied impression techniques, the addition silicones produced more accurate stone casts than the condensation silicones. Therefore, the first hypothesis was accepted. The worse results of condensation silicones can be explained by the significantly continuous polymerization and the evaporation of volatile byproducts, such as ethanol, that can damage the material's dimensional stability and accuracy (7). The addition silicones have excellent mechanical and physical properties and do not form by-products during or after the polymerization reaction (7). All these factors contribute for avoiding the impression material distortion, allowing it to remain dimensionally stable and provide accurate stone casts (1).

The most common dimensional changes that occur with the silicone-based impression materials are related to the material's polymerization shrinkage and to temperature differences between the oral environment and the room where the mold will be stored (thermal shrinkage). The incomplete elastic recovery is another important factor. Some authors (4,10,25) reported that high-viscosity elastomeric impression materials might present little shrinkage and consequently small values of dimensional change due to the high amount of filler. A low matrix/filler ratio leads to the formation of a material with low polymerization shrinkage (25). However, a high amount of filler makes the material less elastic and fluid, resulting in a reduced accuracy (4,25). The variation of the composition of each material may cause differences in the mechanical and chemical properties among materials of the same type, which explains the small difference found in this study for the addition silicones (Aquasil and Express).

No difference was found among the three impression techniques in this study, neither in other researches that showed that the dimensional accuracy alteration is not dependent on the used impression technique (3,8,14,21,22). Thus, the second hypothesis was also accepted. Furthermore, despite the statistically significant differences found in the elastomeric impression materials, all impression materials and techniques produced accurate casts as recommended

by the 4823:2000 ISO standard (11). In this *in vitro* study the detachment movement between stainless steel cast and tray was standardized to minimize the effects of tilting movement on the mold accuracy. Clinically, the tray removal movement from oral cavity is a critical process that may compromise the mold accuracy.

Several clinical and laboratory steps should be considered for the correct choice of impression technique. The monophasic technique seems to be the easiest because it uses only one material with a single viscosity. However, the need to make the first impression in order to manufacture the individual tray with internal relief increases the required clinical sessions (24). It is not indicated that these trays be used on the same day of its fabrication because most acrylic resin shrinkage occurs during the first 10 h. The application of an adhesive tray is needed also to provide better adhesion of the material to tray (24) and minimize the tensions between the tray and impression material during the detachment movement between tray and oral cavity (9). In the 2-step putty/light-body technique care should be taken for the correct replacement of mold in the patient's mouth and the need of a relief that may cause stress in the impression material. Any mistake in these steps can cause distortions that will result in dimensional accuracy alterations (18). The 1-step putty/light-body technique reduces chair time to allow one impression with two materials, but a simultaneous shrinkage of materials with different viscosities and characteristics occurs. Furthermore, the reproduction of details may be performed by the putty material and not by the light-body material. This situation as well as the presence of bubbles in the impression material (6) can occur by excessive pressure applied during the impression and consequent flow of the light-body material (18). The need of a second person to aid the material handling is another factor to be considered.

It seems that the factors that affect the reproduction and accuracy of molded structures are associated more with the impression materials than the impression technique (3). Different protocols, such as the application or not of adhesives in trays (18), may explain the differences found among the studies regarding the impression techniques. The choice of a product for a particular clinical application should be based on the material's properties rather than on the type and class of impression material. Dental professionals should be informed about the advantages and disadvantages of each material and impression techniques to adequately use them in clinical practice and provide proper clinical longevity to the prosthetic treatment. Based on the results of this study, it is recommended that dentists use the technique that they are most familiar with, respecting the limitations of each technique, as laboratory studies control several factors that may cause mold distortion.

## Resumo

O objetivo deste estudo foi mensurar e comparar a precisão dimensional de modelos de gesso de um arco mandibular parcialmente edêntulo feitos a partir de dois silicões por condensação, dois silicões por adição e três técnicas de moldagem (dupla mistura, reembasamento e moldeira individual). Um modelo metálico padrão de um arco mandibular parcialmente edêntulo foi obtido com pontos de referência nos caninos mandibulares permanentes esquerdo e direito, e segundo molares mandibulares permanentes esquerdo e direito. As distâncias anteroposteriores (entre o canino e segundo molar mandibulares esquerdos e entre o canino e segundo molar mandibulares direitos) e as distâncias transversais (entre os caninos mandibulares esquerdo e direito e entre os segundos molares mandibulares esquerdo e direito) do modelo metálico foram mensuradas através de um microscópio com 30x de aumento e 0,5 µm de precisão. Todas moldagens foram feitas com silicões por condensação e adição. As técnicas de dupla mistura e reembasamento foram realizadas com materiais nas viscosidades massa e leve e a técnica da moldeira individual somente com material leve. Após os procedimentos de moldagem, a precisão de cada material e técnica foi aferida medindo os modelos de gesso vazados (n=5) dos moldes, sob o mesmo microscópio. As diferenças entre os valores dos modelos de gesso e do modelo metálico foram calculadas, apresentadas como porcentagens e analisadas estatisticamente através da análise de variância e teste de Tukey ( $\alpha=0,05$ ). Todas as distâncias mensuradas nos modelos de gesso apresentaram dimensões alteradas com alterações lineares negativas (contração) significativas quando comparadas as medidas do modelo metálico. Os modelos de gesso feitos a partir de silicões por adição foram dimensionalmente mais precisos. Não foram encontradas diferenças entre as técnicas de moldagem.

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