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Dimensional accuracy of alginate mold method on duplication of stone casts

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ABSTRACT

Introduction: Accurate duplication of casts is necessary to fabricate a proper prosthetic appliance with good adaptation. Alginate is an inexpensive impression material and is available in most dental offices. The aim of the present study was to evaluate the accuracy of the casts duplicated using alginate impression mold.

Materials & Methods: In this in vitro study, at first, a metallic tray and condensational silicone impression material were used to prepare 60 master impressions of a maxillary dental model. The impressions were poured using stone gypsum, and their dimensions were measured via a digital Vernier caliper with accuracy of 0.01 mm. Then, the casts were fixed on the floor of a flask filled with alginate with two folds volume of cold water recommended by the manufacturer. The resulting impressions were immediately poured, and the measurements were repeated. The data were analyzed with SPSS 26 using MANOVA and ICC index ($p<0.05$).

Results: Statistical analyses showed that dimensional changes of the duplicated casts were not significant relative to the master casts (P=0.90). In addition, insignificantly, the duplicate casts were smaller than the master casts and the dimensional changes in the transverse dimension were more than those in the anteroposterior dimension.

Conclusion: The results indicated that alginate duplicate impressions taken using the alginate molding technique had good dimensional accuracy when they were poured immediately. Since alginate is inexpensive, this technique can be used in the dental office by saving time to decrease laboratory costs and avoid using expensive impression materials.

Keywords: Calcium Sulfate, Dental Facilities, Dental Models

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Introduction

Stone casts are duplicated for a variety of reasons, including a lack of access to the patient, having an extra cast if the master cast is broken, and archiving casts.[1] Of the various impression materials, agar hydrocolloids and alginate are effectively used for duplicating casts due to their elasticity.[2, 3] The agar used in the duplication process requires a phase change in a thermal preparation unit, which might distort the block-out material of the partial denture cast.[4] Alginate is an irreversible hydrocolloid with good accuracy, easy use, and low cost, which have made it one of the most favorable impression materials.[2, 5] Previous studies have shown that if the impressions are poured immediately (even 10-120 minutes after taking the impression), the most accurate casts will be achieved.[6-9]

Usually, using a tray to duplicate casts with alginate results in the distortion of alginate impressions.[7] Ercoli et al (1996) published a report on the use of alginate impression material for accurate and easy duplication of casts in the dental office, explaining the relevant procedural steps. However, they did not evaluate the dimensional accuracy of the duplicated stone casts.[10] Therefore, the present study aimed to evaluate the dimensional accuracy of stone casts prepared using alginate impression material.

Materials & Methods

The ethical approval was obtained from the Ethics Committee of Zanjan University of Medical Sciences (IR.ZUMS.REC.1399.108). In this in vitro study, the model used was an acrylic dental model of the maxilla (HS217, Hoss Ban Mandegar, Tehran, Iran) with fixed teeth. An extra-large (XL) perforated metallic tray (6000/U6, Medesy, Maniago, Italy) and condensational silicone impression material (Speedex, Coltene, Altstatten, Switzerland) were used for the initial one-step impression taking with the putty-wash (light body) method. After 8 minutes and complete setting of the wash layer of Speedex impression material, the tray was separated from the dental model with light pressure.[11] Next, stone gypsum (Tara, Kheyzaran, Isfahan, Iran) was mixed with adequate water (100 g of powder with 30 mL of water) according to the manufacturer's instructions, and the impression was filled on the vibrator. After one hour, the stone cast was separated from the impression and allowed to dry completely for 24 hours.[12] Sixty stone casts according to the following formula were prepared from the model and numbered using this technique.

$$n_1 = n_2 = \frac{\left[z_{1\frac{\alpha}{2}} + z_{1-\beta}\right]^2 (\sigma_1^2 + \sigma_2^2)}{d^2} = \frac{(1.96 + 0.84)^2 * (0.13^2 + 0.13^2)}{(0.067)^2} = 60$$

A digital Vernier (LCD Digital Caliper Silver, Instar, Hangzhou, China) accurate to 0.01 mm was used to measure the following parameters:

1.Inter-canine width: The linear distance between the cusp tips of the canine teeth on the right and left sides of the dental arch

2.The transverse distance between the first premolars: The linear distance between the tips of the buccal cusps of the first premolars on the right and left sides of the dental arch

3.The transverse distance between the second premolars: The linear distance between the tips of the buccal cusps of the second premolars on the right and left sides of the dental arch

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4.The transverse distance between the first molars on the mesiobuccal cusp: The linear distance between the tips of mesiobuccal cusps of the first molars on the right and left sides of the dental arch

5.The transverse distance between the first molars on the distobuccal cusps: The linear distance between the tips of the distobuccal cusps of the first molars on the right and left sides of the dental arch

6.The incisor-canine distance: The linear distance between the mid-point on the incisal edge of the central tooth (determined by the Vernier) and the tip of the canine tooth cusp in the left and right quadrants

7.The canine-molar distance: The linear distance between the canine tooth cusp tip and the distobuccal cusp tip of the first molar in the left and right quadrants

8.Incisor-molar distance: The linear distance between the mid-point on the incisal edge of the central tooth and the distobuccal cusp tip of the first molar in the left and right quadrants (Figure 1). [6, 13]

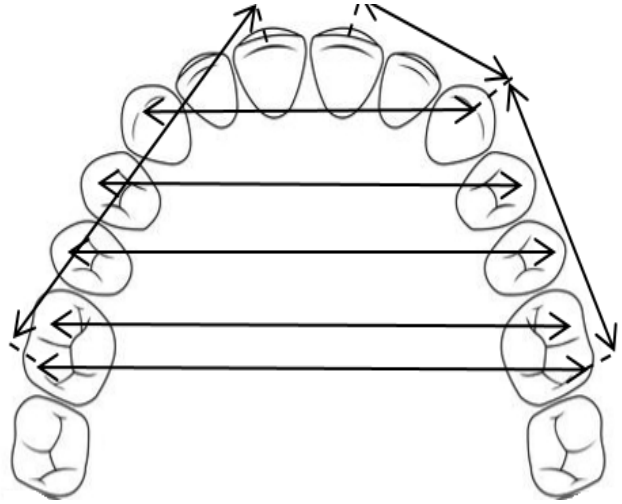

Figure 1. Measurement dimensions on the cast

The master casts were immersed in slurry water for 15 minutes before the duplication procedure.[14] Then the master cast was fixed on the floor of the duplication flask (Duplication Flask, Dandiran, Tehran, Iran) with sticky wax (Ivory wax, Pyrax, Roorkee, India), and the flask cavity was placed on it. Cold water, twice that recommended by the manufacturer[10, 15], was used to achieve sufficient flow of alginate (Chromaprint, Coltene, Rio de Janeiro, Brazil) to make it flow into the flask (1:4, powder-to-liquid ratio), which was poured into the flask immediately after achieving a homogenous consistency. Three minutes after the alginate impression material set, the cast was separated with a spatula and air spray pressure. The impression was immediately poured with stone gypsum on a vibrator according to the manufacturer's instructions.[10] After one hour, the duplicated cast was removed.

Stone casts with clearly visible distortion, granulated and rough surfaces, and poorly recorded incisal edges and buccal cusp tips were excluded. Sixty master stone casts were duplicated and numbered 24 hours after complete drying.[6, 7, 12] The measurements were carried out similar to those on the master cast. Measurements on each stone cast were made twice with a 1-week interval, and their means were calculated and recorded. One operator carried out all the impression taking, impression pouring, and measurement procedures to minimize human errors and improve accuracy.[12] The measurements for each duplicated cast were compared with its corresponding master cast. The means of measurement data were coded and analyzed with SPSS 26 using MANOVA and ICC two-way mix ANOVA consistency index. Statistical significance was set at $P<0.05$.

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Results

The present study compared the mean dimensions of the master and duplicated casts with the alginate impression method. The mean differences in the measurements in all the dimensions were negative and in most casts close to zero (Table 1). The ICC index for most dimensions indicated similarity between the master cast and duplicated cast groups. Since the ICC index was not significant in the inter-canine distance (P=0.512), there was no similarity only in this dimension; however, there were similarities in all the other distances considering the P-values (P<0.001), although the similarity was lower in the incisor-molar distance on the left side and the transverse distance between the second premolars than the other distances (Table 2).

Table 1. Mean and standard deviation of difference and percentage of difference between duplicated and master cast at different dimensions in millimeter

Distance	Minimum	Maximum	Average difference	percentage of average difference	standard deviation
Inter-canine width	-0.16	0.05	-0.01	-0.04	0.040
Inter-first premolar width	-0.13	0.09	-0.02	-0.04	0.037
Inter-second premolar width	-0.19	0.04	-0.04	-0.08	0.049
Inter-first molar width at MBCT	-0.16	0.09	-0.03	-0.06	0.057
Inter-first molar width at DBCT	-0.14	0.13	-0.02	-0.05	0.061
Right incisor-canine distance	-0.15	0.12	-9.3×10^{-3}	-0.04	0.047
Left incisor-canine distance	-0.16	0.10	-4.9×10^{-3}	-0.02	0.044
Right canine-molar distance	-0.09	0.12	-2.5×10^{-3}	0	0.036
Left canine-molar distance	-0.16	0.06	-6.1×10^{-3}	-0.01	0.037
Right incisor-molar distance	-0.13	0.09	-0.01	-0.02	0.034
Left incisor-molar distance	-0.15	0.13	-4.4×10^{-3}	0	0.053

Table 2. ICC index values to evaluate the two cast sizes relative to each other at different dimensions

Distance	ICC	Lower bound	Upper bound	Significance
Inter-canine width	4.00×10^{-3}	-0.25	0.24	0.512
Inter-first premolar width	0.68	0.52	0.79	<0.001
Inter-second premolar width	0.54	0.33	0.69	<0.001
Inter-first molar width at MBCT	0.64	0.46	0.76	<0.001
Inter-first molar width at DBCT	0.65	0.48	0.78	<0.001
Right incisor-canine distance	0.70	0.54	0.81	<0.001
Left incisor-canine distance	0.81	0.70	0.88	<0.001
Right canine-molar distance	0.85	0.76	0.90	<0.001
Left canine-molar distance	0.60	0.42	0.74	<0.001
Right incisor-molar distance	0.85	0.76	0.91	<0.001
Left incisor-molar distance	0.39	0.16	0.59	0.001

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The results of MANOVA showed that, generally, changes in the duplicated casts were not significant compared to the master cast (P=0.090). The study power was calculated at 0.87, considering a lack of significant differences in the analyses. Thus, finally, it can be concluded that there were no significant differences between the master cast and duplicated casts.

Discussion

In the present study, the mean dimensional changes of the duplicated casts were negative compared to the master cast, indicating that overall the duplicated casts had decreased in size compared to the master cast. The dimensional changes of alginate are multifunctional and depend on the characteristics of the material.[6] In the present study, possibly the most important factor was water sorption.

Immediately after gel formation, a large volume of free water might be preserved within the fillers of the alginate material. This storage of water results in the swelling of the impression, especially in the peripheral areas, decreasing the size of the cast, consistent with a study by Imbery et al, in which the extended-pour alginate impressions that were poured immediately exhibited expansion.[12] In a study by Amirian et al, the reason for the cast's shrinkage was reported to be shrinkage in the alginate impression, which is different from the present study.[8] In other studies, too, the alginate impressions underwent shrinkage due to the evaporation of water or syneresis.[6, 7, 15] The palatal area of the cast duplicated using alginate impression material was smaller than the master cast, especially in the width between the premolars and the width between the first molars on the mesiobuccal cusps, consistent with other studies.[8] After the initial expansion, shrinkage occurs, which is more probable at the center of the palatal mass. Since the bulk of the material occurs between the second premolar and first molar teeth on the left and right sides (i.e., the deepest area of the palate), dimensional changes occur as a decrease in the distance between these teeth. It is possible that an extensive initial expansion in the peripheral areas of the master cast, followed by shrinkage at the center of the palate, results in a decrease in the transverse dimension.

In the present study, the dimensional changes in the inter-canine area, too, were significant. The possible reason is that the canine cusp tips were not sharp in the master model used for taking impressions, leading to errors in measuring the inter-canine distance with the Vernier. The ICC index showed similarities in the measurements of the master and duplicated casts in all the distances. Statistical analyses showed no significant differences in the overall sizes of the two casts. Based on these results, the null hypothesis indicating no significant dimensional differences between the master cast and the casts duplicated with alginate impressions was not rejected.

In the present study, doubling the water volume in the alginate material compared to the manufacturer's instruction (4:1 water-to-liquid proportion) increased the material's flow on the cast surface to properly record the fine details on the master cast.[4, 16] No studies are available on the effect of powder-to-liquid ratio on the dimensional stability of alginate impressions. It appears that this property is mainly related to the ability of alginate to maintain water within the mass, with no effect on the dimensional accuracy of the impressions.[15]

Based on previous studies, there are no clinically significant differences, such as distortion between alginate impression materials mixed manually or with a mixer.[9] Therefore, this factor, too, cannot significantly affect dimensional stability. Based on a study by Thonghammachat et al., the maximum clinically acceptable change might be 90–240 µm, i.e., in the range of the PDL space.[17] In the present study, the maximum dimensional change was 0.04 mm (i.e., 40 µm), which is in the acceptable range. In the present study, a digital Vernier with 0.01 mm accuracy was used to measure the distances. Previous studies have shown that the manual method with a digital

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Vernier is highly accurate and at the level of the gold standard [18, 19], with no significant differences between the manual and digital methods.[20] Techniques such as light microscopes do not have clinical applications despite accuracy rates of <1 µm because the crystal structures of gypsum products cannot reconstruct such accuracy.[12]

The results of the present study showed that the alginate materials method has acceptable accuracy for duplicating gypsum casts. Therefore, the method used in the present study is undeniably easy to apply, saves time, and is superior to complicated and costly laboratory techniques. One of the limitations of this study is the use of a specific brand of alginate that may not be generalizable to other brands. One of the practical limitations of this study is the use of a flask, which may limit the clinical application of the above duplication method. It is suggested that the present study be repeated and supplemented with other alginate brands to achieve more reliable results. It is also suggested that future studies determine and evaluate changes in the vertical dimension too. The use of more clinical methods for duplication is also suggested in future studies.

Conclusion

The present study showed that casts duplicated with alginate impression material using a duplicating flask were not significantly different from the master cast in their dimensions. Since alginate is inexpensive, this technique can decrease the laboratory and impression material costs and produce casts with good dimensional accuracy.

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Conflicts of Interest

The authors certify that they have no conflict of interest.

Authors' Contribution

N. Naderi helped in data acquisition, data analysis, and manuscript writing. M. Sheikhi helped with contributing to the conception, study design, revising, and editing manuscript. H. Ariamanesh and S. Pezeshki and MM. Mohammadi helped with study design, manuscript drafting, and data collection. All authors read and approved the final manuscript.

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