Original Article

Effect of Core Materials on the Dimensional Accuracy of Casts Made of Two Different Silicone Impression Materials: An Experimental Study

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ABSTRACT

Background and Aim: Dimensional accuracy of impressions is crucial to the quality of fixed restorations. This accuracy can be highly affected by the type of core and impression materials. This study aimed to assess the effect of different core materials on dimensional accuracy of two silicone impression materials. **Materials and Methods:** In this *in vitro* study, three master core models were fabricated of amalgam, composite resin, and nickel–chromium. Of each model, 30 impressions were taken; 15 with additional and 15 with condensational silicone impression material. The accuracy of impressions of the three core materials was assessed by measuring two linear dimensions and one vertical dimension on the stone casts. **Statistical Analysis:** Data were analyzed with two-way analysis of variance and Scheffe *post hoc* test ($\alpha = 0.05$). **Results:** Accuracy of the three measured dimensions was significantly affected by both the impression and core materials ($P < 0.05$). Additional silicone was significantly more accurate in linear dimensions, and impressions of the amalgam core were significantly more accurate than other cores in linear dimensions. **Conclusion:** Additional silicone impression material had more detail reproduction, and the impressions of amalgam core were more accurate than the composite and nickel–chromium core materials.

KEYWORDS: *Cast, core material, dimensional accuracy, fixed restoration, impression material, oral prostheses*

INTRODUCTION

Successful fabrication of fixed prosthodontic primarily requires a high-quality dental impression. Quality of that impression relies, in turn, on the dimensional stability, accuracy, and flexibility of the elastomeric impression materials, and the used technique.[1] A recent clinical study accentuated the accuracy problem of impressions, reporting that around 89% of the studied impressions had at least one obvious error. Seemingly, the clinicians must scrutiny the impressions more critically.[2] Introduction of the computer-aided design–computer-aided manufacturing and three-dimensional imaging systems has yielded remarkable technical improvements; yet, conventional impression making still contributes to converting the patients' information to laboratory data.[3]

Among the commercially available impression materials, condensational and additional silicones are more commonly used than others.[4] In the condensational silicon impression material, the polycondensation process is followed by alcohol release, and consequently impression contraction.[5] The additional silicone impression material is superior due to the impression precision, slight contraction, and high elasticity.[6]

Depending on the used materials and the included steps, the techniques of impression making are either

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monophase or double phase. The double-phase technique, which can be performed in one or two steps, makes use of impression materials of different viscosity. Studies have shown that the two-step putty/light-body technique is more accurate than the one-step technique. With the two-step technique, first, the putty is polymerized and allowed to contract; then, the impression is made with the light-body material. In such a way, further contractions of the light-body material cause only minor dimensional changes. An impression can be more accurate if the volume of polymerizing material is reduced at each stage, resulting in further decrease of the final contraction.[7,8]

Better dental care and successful endodontic treatment have improved the longevity of natural dentition. Hence, there is a higher demand for restoring the tooth surfaces compromised by caries, trauma, and endodontic treatment. Such cases generally require a base material to replace the missing tooth structure, and then an indirect restoration.[9] But, to restore more terrific dental damages, a core buildup material is needed to make up for the bulk, besides a fabricated indirect restoration.[9] Type of the core buildup is determined based on the present volume of the tooth structure. Core placement is recommended in cases that have lost more than half of the coronal part of the tooth.[10] Core buildup restorations serve as a basement for the tooth, which let the dentist create the desired retention and resistance forms during the preparation phase. Hence, the core material highly influences the outcome of indirect restorations. Core restorations can be made of several materials such as nickel–chromium (Ni-Cr) cast cores, amalgam, composite resin, zirconia, and porcelain.[11]

Studies reported the addition-type silicones as one of the most dimensionally accurate materials for making impression.[12,13] Owing to the recent improvements in impression materials, dimensional accuracy is currently more dependent on the adopted impression technique rather than the material itself.[7,12] Nonetheless, some studies have claimed that the impression technique has no impact on the dimensional accuracy of impressions.[14]

Accuracy of impressions has been addressed in relation to the materials and/or techniques. Yet, no study has investigated the effect of different types of core buildup materials on the dimensional accuracy of silicone impression materials. Therefore, this study was designed to evaluate the effect of three core buildup materials (Ni-Cr, amalgam, and composite resin) on the dimensional accuracy of additional and condensational silicone impression materials made through two-step impression technique. The null hypothesis was that different core buildup materials and silicone impression materials have no influence on the dimensional accuracy of casts.

MATERIALS AND METHODS

STUDY DESIGN

This experimental *in vitro* study was conducted in Biomaterials Research Center of Shiraz University of Medical Sciences in 2019, and was approved by the Ethics Committee of Shiraz University of Medical Sciences (IR.SUMS.REC.1396.S3). A stainless steel master die was used to resemble a full veneer crown preparation, as was formerly tested in a study by Bailey *et al.*[15] Accordingly, the vertical dimension was 12 mm from the cavosurface to the occlusoaxial line angle, the diameter was 13 mm at the cavosurface with convergence angle of 5°, creating a 9-mm diameter at the occlusal end of the die, and shoulder width of 1.5 mm.

STUDY METHOD

Three measurements were made from the marked reference lines, one vertical and two horizontal. Two perpendicular lines were marked so they crossed each other in the middle of occlusal surface. Four points (A, B, C, and D) were considered on the occlusal surface on which the circle crossed the marked lines. The distance between the two points (AB and CD) along each marked line was measured as the horizontal dimensions. Two lines were marked on the surface of axial wall perpendicular to the long axis of the die, between the two previous horizontal lines, one located 1 mm below the upper line angle, and the other located 1 mm occlusally from the axiogingival line angle. Another line was scribed along the vertical axis of the die. The measurement between the horizontal lines on the vertical axis line was referred to as EF dimension. The position of EF line in relation to the AB and CD dimensions was the guide to distinguish the AB and CD dimensions [Figure 1].

The polytetrafluoroethylene molds were made of the master die for preparing three core specimens, including amalgam, composite resin, and Ni-Cr. The composite resin core (Tetric Ceram HB composite resin; Ivoclar Vivadent, Pforzheim, Germany) was built up in four 3-mm high incremental layers. Each layer was light polymerized with a light-emitting diode device (Radipus LED; SDI, Victoria, Australia) at 1000 mW/cm² for 20 s. The amalgam core specimen (Airel Pharma, Champigny-sur-Marne, France) was made through simply packing amalgam into the mold. The Ni-Cr core (Durabond; Matech, Camarillo, California)

was fabricated through making wax of the same shape and dimensions by using the fabricated mold. The lost wax technique was used for casting the Ni-Cr alloy in an induction casting machine (Pressovac; Aseg Galloni, Milan, Italy).

By using a surveyor, each core specimen was placed in a machined stainless steel base [Figure 1]. All the specimens were stored in distilled water at room temperature for 24 h to complete the setting time of amalgam core, besides completion of an additional acid–base setting reaction of composite resin core. Storage in distilled water also induced the delayed expansion of composite resin core due to the moisture sorption before impression making, as in clinical condition. Then, 30 impressions, 15 with additional silicone (Bisico; Bielefelder Dentalsilicone, Bielefelder, Germany) and 15 with condensational silicon (Speedex Coltene; Asia Chemi Teb, Tabriz, Iran, under the license of Coltene Switzeland) were made from each master core specimen by using a perforated machined stainless steel tray [Figure 2]. Wax spacer of 1-mm thickness was placed over the core specimens to create uniform space to accommodate the subsequent light-body material.

The impression was made through two-step technique. All materials were mixed in standard proportions recommended by the manufacturer. The tray surface was uniformly covered with the adhesive supplied by the manufacturer. As the impressions were made at the room temperature instead of the oral environment, the setting time was doubled according to the manufacturer to compensate for the temperature difference.

In the first step, the putty impression was made and allowed to set for 10 min. In the second step, the wax spacer was removed and wash material was added. The impression was reseated and allowed to set on the master core model for 12 min.

Type IV gypsum (Tewerock; Kettenbach, Hesse, Germany) was used to pour the dies. On the basis of the recommended ratio, 20 mL of distilled water was added to 100 g of powder. The powder and water were first mixed by hand for 10 s, then vacuum mixed (Multivac 4; Degussa, Hanau, Germany) for 30 more
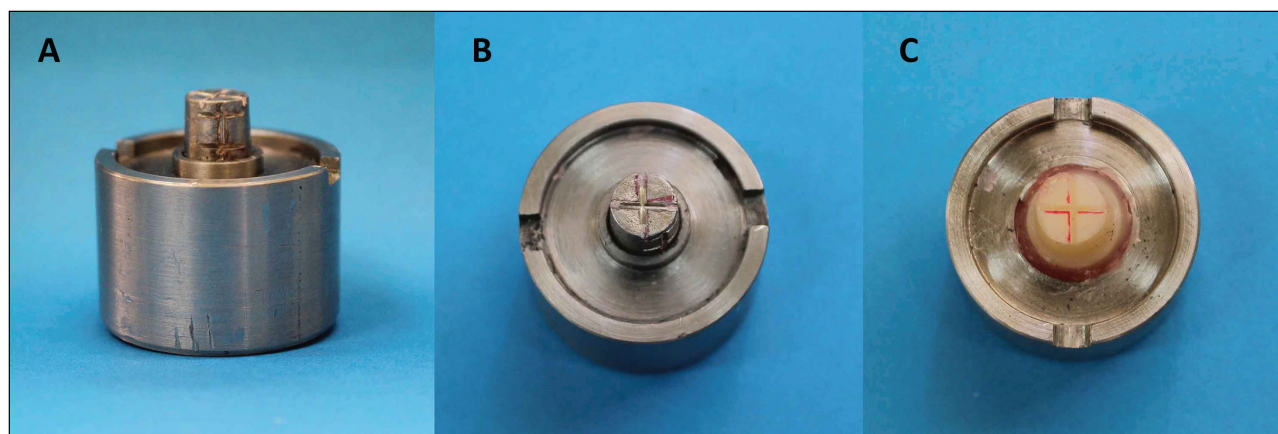

Figure 1: (A) Ni-Cr core model. (B) Amalgam core model. (C) Composite resin core model
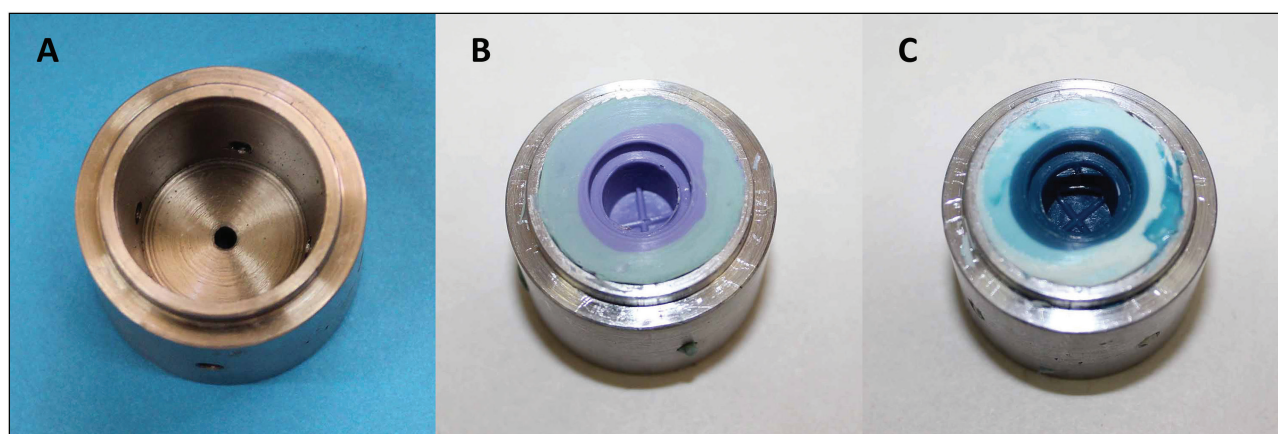

Figure 2: (A) Perforated metal tray. (B) Additional silicone impression. (C) Condensational silicone impression

seconds. The gypsum was vibrated into the impressions and allowed to set for 60 min before separation from the impressions [Figure 3].

OBSERVATIONAL PARAMETERS

Measurements of the master core and stone models were carried out with a stereomicroscope at ×30 magnification (BS-3060C; BestScope, Beijing, China), capable of measuring up to 0.00001 mm. This microscope was attached to a two-dimensional data processor (ScopeImage 9.0, Nanjing Novel, Nanjing, China). Crosshairs were put on the starting point, and then, the endpoint and both positions were electronically recorded. The distance between the two points appeared on a digital readout.

All the procedures throughout the investigation were performed by a single operator, so as to eliminate multi-operator optical error in crosshair alignment of the microscope. Measurements were repeated three times for each distance (AB, CD, and EF) on the master core models (composite resin, amalgam, and Ni-Cr) at each measurement location. The mean of all distance measurements was calculated, and this value served as the control to be compared with the two impression materials. Measurements were repeated three times on each stone die.

The distance between the mean of stone models (msm) and the mean of master core model (mmm) divided by the mean of master model multiplied by 100 was expressed as the percentage of deviation from the master model for each core and impression materials of each measurement location.

$$Percentage\ of\ deviation = \frac{(msm - mmm)}{(mmm)} \times 100$$

STATISTICAL ANALYSIS

Test was performed using the Statistical Package for the Social Sciences software, version 20.0 (SPSS, Chicago, Illinois). Shapiro–Wilk test was carried out to assess the hypothesis of normal distribution. The assumption of homogeneity of variances among the groups was tested with Levene's F test. The mean percentage of deviation

and absolute change of each group for each dimension were analyzed via two-way analysis of variance (ANOVA), with full factorial model. Moreover, one-way ANOVA, Scheffe *post hoc* test and independent sample t test were used to compare the core materials and impression materials, respectively. In all the tests, P value <0.05 was considered to be statistically significant. Power analysis showed that the sample size in each subgroup ($n = 15$) was sufficient to assess the effects of different core and impression materials on the dimensional accuracy of resultant casts.

DISCUSSION

Table 1 summarizes the results of two-way ANOVA. According to the findings of this study, both the impression and core materials significantly affected the percentage of deviation and absolute change of the three measured dimensions (AB, CD, and EF) ($P < 0.05$). Moreover, interaction of the two factors significantly affected the percentage of deviation of AB and EF dimensions ($P < 0.05$).

Table 2 presents the mean and standard deviation of the percentage of deviation, and Table 3 shows that of the absolute change of both impression materials group and the three core materials subgroups for each measured dimension (AB, CD, and EF). According to the results of independent t test, in amalgam and Ni-Cr core materials for both linear (horizontal) dimensions (AB and CD), the additional impression material was significantly more accurate (lower percentage of deviation and absolute change) than the condensational silicone. However, in composite core material no significant difference was observed between the two impression materials. Both impression materials decreased the linear (horizontal) dimensions of all the three core materials. On the contrary, the vertical dimension (EF) for the composite and Ni-Cr core materials, decreased in the additional silicone, and increased in the condensational silicone impression materials ($P < 0.05$).

Having compared the core materials with respect to the impression material (Scheffe *post hoc* test), the results
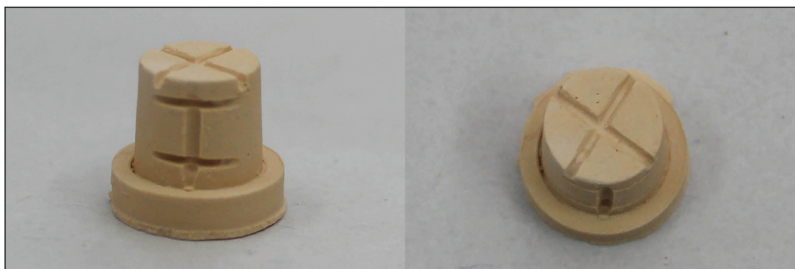

Figure 3: Stone model

Table 1: Results of two-way analysis of variance

Variables	Factor		Statistical indices	
			F value	P value
Percentage of deviation (%)	AB	Impression material	17.65	<0.001
		Core material	23.77	<0.001
		Impression material × core material	4.66	0.012
	CD	Impression material	28.08	<0.001
		Core material	38.22	<0.001
		Impression material × core material	3.084	0.051
	EF	Impression material	24.98	<0.001
		Core material	4.41	<0.015
		Impression material × core material	3.26	0.043
Absolute change	AB	Impression material	12.18	0.001
		Core material	22.62	<0.001
		Impression material × core material	3.45	0.036
	CD	Impression material	24.21	<0.001
		Core material	43.21	<0.001
		Impression material × core material	2.36	0.100
	EF	Impression material	6.92	0.010
		Core material	7.25	0.001
		Impression material × core material	2.19	0.118

Table 2: Mean and standard deviation of percentage of deviation of different impression and core materials for AB, CD, and EF dimensions (%)

Variables		Deviation (%)			T (P) (between impression materials)		
		AB	CD	EF	AB	CD	EF
Additional silicone	Amalgam	-2.37 ± 1.68	-0.87 ± 1.59	-3.09 ± 1.58	2.08 (0.046)	3.62 (0.001)	0.86 (0.393)
	Composite	-5.10 ± 1.72	-4.44 ± 1.49	-2.78 ± 1.47	0.252 (0.803)	1.106 (0.278)	10.32 (<0.001)
	Ni-Cr	-3.64 ± 0.99	-3.06 ± 1.74	-2.05 ± 1.19	6.59 (<0.001)	4.34 (<0.001)	6.71 (<0.001)
	F (P)	11.40 (<0.001)a	19.13 (<0.001)b	2.09 (0.136)	-	-	-
Condensation silicone	Amalgam	-3.53 ± 1.41	-2.74 ± 1.34	-1.60 ± 6.48	-	-	-
	Composite	-5.23 ± 1.17	-4.97 ± 1.14	2.40 ± 1.31	-	-	-
	Ni-Cr	-5.86 ± 0.88	-5.23 ± 0.93	0.42 ± 0.84	-	-	-
	F (P)	16.76 (<0.001)c	22.47 (0.001)d	4.32 (0.019)e	-	-	-

F = F test value, T = t test value, P = P value, Ni-Cr = nickel chromium

aAmalgam and composite (P < 0.001), composite and Ni-Cr (P = 0.038)

bAmalgam and composite (P < 0.001), amalgam and Ni-Cr (P = 0.002)

cAmalgam and composite (P = 0.001), amalgam and Ni-Cr (P < 0.001)

dAmalgam and composite (P < 0.001), amalgam and Ni-Cr (P < 0.001)

eAmalgam and composite (P = 0.019)

showed that in both types of impression materials, the amalgam core had significantly lower percentage of deviation and absolute change than the composite resin and Ni-Cr core materials for horizontal dimensions (AB and CD) [Figures 4 and 5]. Regarding the vertical dimension (EF), the Ni-Cr core material showed lower deviation and absolute change than the composite and amalgam; however, the difference was not statistically significant ($P > 0.05$).

This study investigated the effects of different impression and core materials on the dimensional accuracy of duplicate dies. The findings rejected the null hypothesis, as the dimensional accuracy was significantly affected by both variables (impression and core materials). Research has announced that the dimensional accuracy of silicone impression materials can be affected by multiple factors such as the kind of viscosity, thickness of impression material, impression technique, the tray type, storage time, release of by-product, polymerization and thermal contraction, and incomplete elastic recovery.[16,17]

In this study, the impressions were made through the double-phase two-step technique with 1-mm spacer. It was previously reported that the two-step technique with uniform spacer had the slightest dimensional changes compared to other impression techniques.[18,19] If a layer

Table 3: Mean and standard deviation of absolute change (µm), according to the impression and core materials for AB, CD, and EF dimensions

Variables		Absolute change			T (P) (between impression materials)		
		AB	CD	EF	AB	CD	EF
Additional silicone	Amalgam	-269.91 ± 112.82	-50.21 ± 118.00	-1076.06 ± 1591.42	2.08 (0.046)	3.62 (0.001)	0.86 (0.393)
	Composite	-470.08 ± 157.94	-415.08 ± 140.93	-152.58 ± 66.18	0.25 (0.803)	1.10 (0.278)	10.34 (<0.001)
	Ni-Cr	-390.78 ± 59.66	-333.16 ± 212.46	-83.99 ± 45.70	6.59 (<0.001)	4.34 (<0.001)	6.71 (<0.00)
	F (P)	11.08 (<0.001)[a]	20.98 (<0.001)[b]	5.43 (0.008)[c]	-	-	-
Condensational silicone	Amalgam	-341.80 ± 135.77	-482.33 ± 107.35	-553.84 ± 81.43	-	-	-
	Composite	-253.21 ± 116.98	-471.43 ± 107.78	-488.03 ± 74.13	-	-	-
	Ni-Cr	-223.54 ± 908.82	110.67 ± 60.63	16.92 ± 33.70	-	-	-
	F (P)	15.26 (<0.001)[d]	25.45 (<0.001)[e]	1.71 (0.191)	-	-	-

F = F test value, T = t test value, P = P value, Ni-Cr = nickel–chromium
[a]Amalgam and composite ($P < 0.001$), amalgam and Ni-Cr ($P = 0.026$)
[b]Amalgam and composite ($P < 0.001$), amalgam and Ni-Cr ($P < 0.001$)
[c]Amalgam and composite ($P = 0.031$), amalgam and Ni-Cr ($P < 0.001$)
[d]Amalgam and composite ($P = 0.003$), amalgam and Ni-Cr ($P < 0.001$)
[e]Amalgam and composite ($P < 0.001$), amalgam and Ni-Cr ($P < 0.001$)
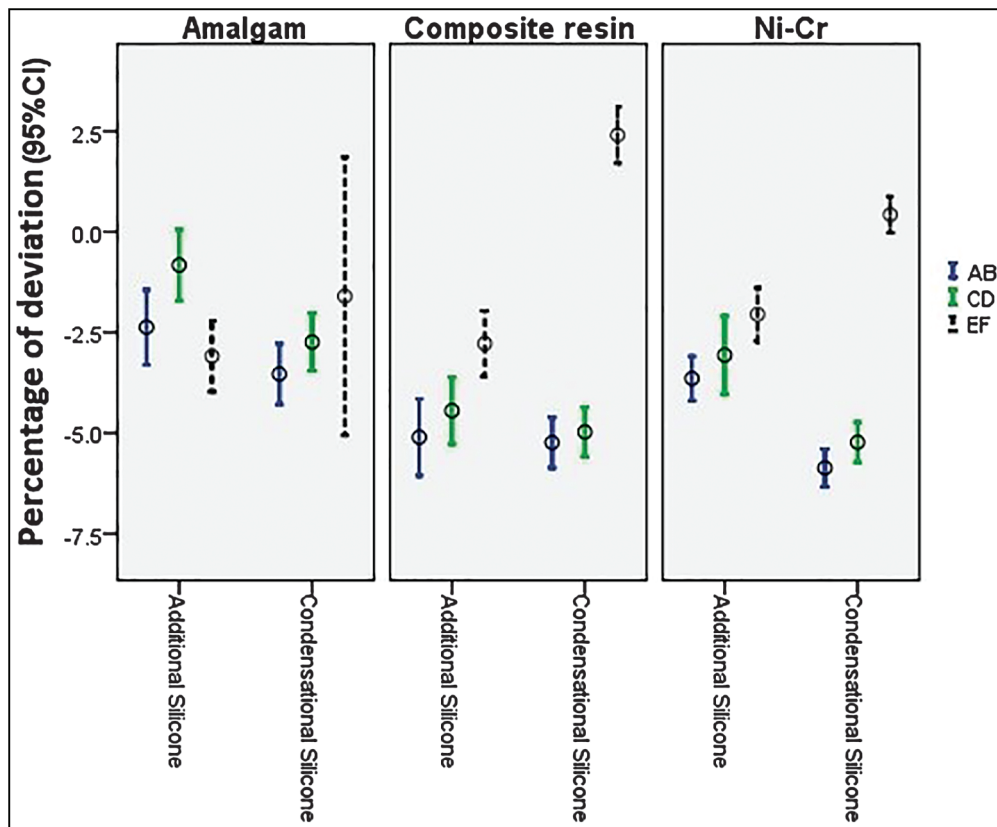

Figure 4: Mean (95% confidence interval) of percentage of deviation (%) according to the impression and core materials for AB, CD, and EF dimensions

of moderate thickness is uniformly distributed, the overall constant deformation of the silicone impression materials would be ignorable.[20] Furthermore, using impression materials of different consistencies and applying them in multistep procedures would help recording the most delicate details of the original.[20]

This study found that the additional silicone was significantly more accurate than the condensational type for recording the horizontal dimensions in amalgam and Ni-Cr core materials. It was also noted that the horizontal dimensional change was negative (contraction) in both materials compared to the control model.
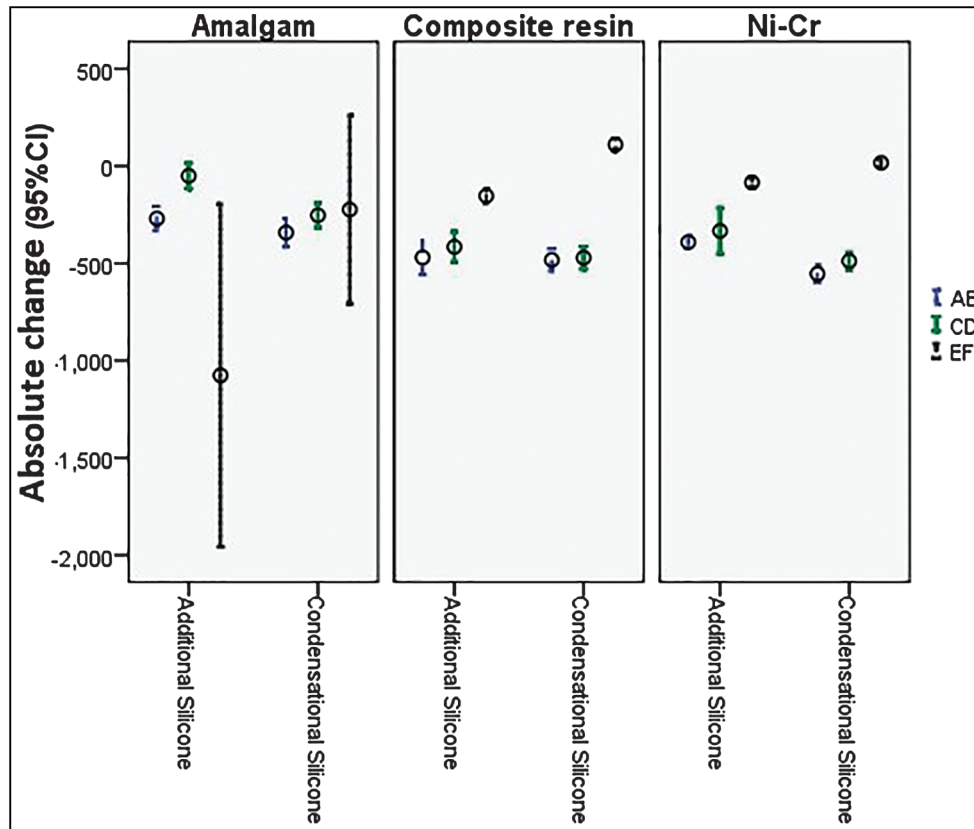
Figure 5: Mean (95% confidence interval) of absolute change (µm) according to the impression and core materials for AB, CD, and EF dimensions

In line with this study, Vitti *et al.*[8] observed higher dimensional accuracy in the plaster model, which was obtained from the additional silicone, compared with the tested condensation silicone. Pande and Parkhedkar[4] as well as Bajoghli *et al.*[21] found that the condensational silicones showed more discrepancy compared with the additional silicones. It was due to the superb elastic recovery of this material and release of no by-product through polymerization of the additional silicone.[22]

Contraction of both impression materials in the horizontal dimensions can be related to the two-step putty/wash technique. It first includes a putty impression, which further serves as a custom tray to contain a wash impression material of low viscosity. The wash material was thought to hydrostatically move the putty while reseating the tray. When the putty has set and is about to be removed, its elastic recovery induces shrinkage in a horizontal plane.[21]

This study also showed that for the composite resin core, no significant difference existed between the accuracy of impression materials in linear dimensions. This can be related to the higher thermal expansion coefficient and continued polymerization shrinkage of composite resin

compared with amalgam and Ni-Cr core materials.[23] It can also be attributed to the delayed expansion of composite resin due to the moisture sorption properties of this material.[24]

The present findings revealed that the additional silicone caused negative, whereas the condensational silicone caused positive percentage of deviation in vertical dimension for composite and Ni-Cr core materials. This was in agreement with the findings of a study by Reddy *et al.*,[22] which reported negative vertical error for the additional silicone. It might be due to the remaining polymerization shrinkage of the additional silicone impression material. The lower vertical dimension can also be attributed to the hydrophilic additives included in the additional silicone impression material, which tend to absorb water and swell when in touch with type IV improved stone.[22]

In a similar study, Johnson and Craig[25] noted that in impression materials with higher polymerization shrinkage such as the condensation silicone, the vertical component of contraction moves toward the occlusal plane of the preparation, where the impression was attached to the tray. As the stock trays are more distant from the occlusal surface to the tray adhesive,

contraction of the occlusal portion of the mold could be more intense. The more intense the contraction is, the higher the height of stone dies would be. Height reduction of the vertical magnitude must be kept to minimum. In fact, a short stone model results in a casting, which would be short and susceptible to developing open gingival margins when put on the prepared abutment. Hence, the additional die spacer should be applied on the occlusal surface of working dies to make up for the slightly shorter working dies in additional silicone impression materials.[26]

Measurements made on the stone cast are likely to be influenced by both the impression material and the linear setting expansion of the used dental stone. Thus, another possible factor may be the use of low expansion (0.0%–0.10%) type IV dental stone in this study, which positively influenced the slightly undersized dimension of the fabricated cast.[27] Reddy *et al.*[27] found that the use of a dental stone of higher expansion (0.28%) increased the dimensions.

This study also detected that the linear dimension was significantly more accurate in impressions of amalgam core material than in composite resin and Ni-Cr cores for both silicone impression materials. It can be due to the lower thermal expansion coefficients of amalgam than the composite resin and Ni-Cr. Excessive expansion and contraction of the core material during thermal change may cause dimensional changes.[11] Besides, the continued polymerization shrinkage inevitably induces high-dimensional changes in composite resin.[23]

The composite and Ni-Cr core materials can benefit from interim restorations during the laboratory phase of prosthodontic reconstruction, so that they would be less exposed to the moisture and thermal changes of the oral cavity, and consequently show lower dimensional changes. Presumably, amalgam should be the core material of choice, whenever possible, to have fixed restorations of higher accuracy and precision.

The limitation of this study was the *in vitro* nature of the study, which did not allow optimal duplication of the oral cavity environment.

With respect to the findings and limitations of this study, it can be concluded that the additional silicone is significantly more accurate than the condensational silicone for recording the linear dimension. Furthermore, the additional silicone decreases, whereas the condensational silicone increases the vertical dimension of composite and Ni-Cr cores. Finally, the impressions of amalgam core are significantly more accurate than the composite resin and Ni-Cr cores in horizontal dimensions for both additional and condensational silicone impression materials.

CONFLICTS OF INTEREST

There are no conflicts of interest.

AUTHOR CONTRIBUTIONS

The study conceived and designed by Dr. Mitra Farzin, Dr. Reza Derafshi, and Dr. Rashin Giti. The experiments were performed by Dr. Rashin Giti and Dr. Reza Derafshi. Data were collected by Dr. Rashin Giti and Dr. Mitra Farzin. Data acquisition and analysis was done by Mohammad Hassan Kalantari and Reza Derafshi. Data were interpreted by Dr. Mitra Farzin and Dr. Rashin Giti. Manuscript was drafted by Dr. Rashin Giti. Final manuscript was reviewed and approved by all authors.

ETHICAL APPROVE

The study was ethically approved by the Ethics Committee of Shiraz University of Medical Sciences (IR.SUMS.REC.1396.S3) in 2017.

PATIENT DECLARATION OF CONSENT

The study did not include any human subject; hence, there was no need to obtain informed written consent from either the patients or their parents for participation in the study and publication of the data for research and educational purposes.

DATA AVAILABILITY

The data set used in the current study is available on request (E-mail: giti_ra@sums.ac.ir).

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