ORIGINAL RESEARCH

Comparison of Dimensional Accuracy of Stone Models Fabricated by Three Different Impression Techniques Using Two Brands of Polyvinyl Siloxane Impression Materials

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Abstract

Aim: The aim of this study is to check the dimensional precision of stone models made by two different brands of polyvinyl siloxane impression materials using the monophase, one-step, and two-step putty/light-body impression techniques.

Materials and methods: A metal model, having two crown preparations, was fabricated. With each technique, 40 impressions were made using two types of polyvinyl siloxane impression materials (Aquasil and Virtual). A total of 240 impressions were made with both the polyvinyl siloxane impression materials. Monophase impressions were made with a medium body using an acrylic custom tray. By simultaneous usage of putty and light-body, one-step impressions were made with a perforated metal stock tray. For two-step impressions, a 25–40 microns thick cellophane sheet spacer was used. The stone casts were obtained from the impressions of the stainless steel model. Three different dimensions (height, diameter, and inter-abutment distance) on these resultant stone casts were compared with the standard die. The accuracy of two different brands of impression materials was also compared. The results were then statistically analyzed.

Results: The resultant casts obtained from the different impression techniques had significantly larger dimensions in height and diameter, but smaller dimensions were observed for the inter-abutment distance. Larger deviation in resultant casts was observed in the monophase than one-step impression technique and the least deviation was observed in the two-step impression technique.

Conclusion: The two-step impression technique produced the most accurate results in terms of the resultant casts. Out of the two different brands, Aquasil produced more fare results.

Clinical significance: Adequate marginal adaptation, proper fit and least distortion of the castings, and the final prosthesis can be achieved by using the adequate impression technique and impression material.

Keywords: Dimensional accuracy, Monophase, One step putty wash, Polyvinyl siloxane, Two step putty wash.

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Introduction

A successful dental prosthesis is dependent on the perfection of many steps in the dental office and impression making is considered the most critical step among all. Making impressions to replicate oral conditions and tooth morphology is an integral part of prosthetic dentistry.[1] Various materials have been used to make impressions for removable and fixed prosthodontics.

Early materials included rigid, semirigid, and elastic compositions such as plaster, zinc-oxide eugenol, compound, and waxes; these materials still have limited uses in dentistry; elastic impression materials can be divided into two large groups: (1) synthetic elastomeric impression materials like polysulfide, condensation silicone, addition silicone, and polyether. (2) Hydrocolloid impression materials like agar agar and alginate. At present, elastometric impression material remains the most popular and accepted material among dentists.

Out of these four elastomeric impression materials, addition silicone provides the best applications in fixed prosthodontics, removable prosthodontics, and implant dentistry.

Polyvinyl siloxane (addition silicone) impression materials were first introduced in the 1970s.[2] They have the least amount of shrinkage on setting and are characterized by excellent dimensional accuracy and long-term dimensional stability. Due to their increased stability, dies can be poured for up to a week after they have been removed from the mouth. If delay in pouring for making dies is anticipated, the addition silicones are the best choice of the rubber impression materials.[3,4]

These impression materials present adequate properties, such as good tear strength and quick elastic recovery. Polyvinyl siloxanes are inherently hydrophobic. Recently, 'hydrophilic' polyvinyl siloxanes have been introduced with better wet moist dental surfaces. These new formulations have intrinsic surfactants added which can be more readily poured up with a gypsum-based die stone than the previous generation materials.[4,5]

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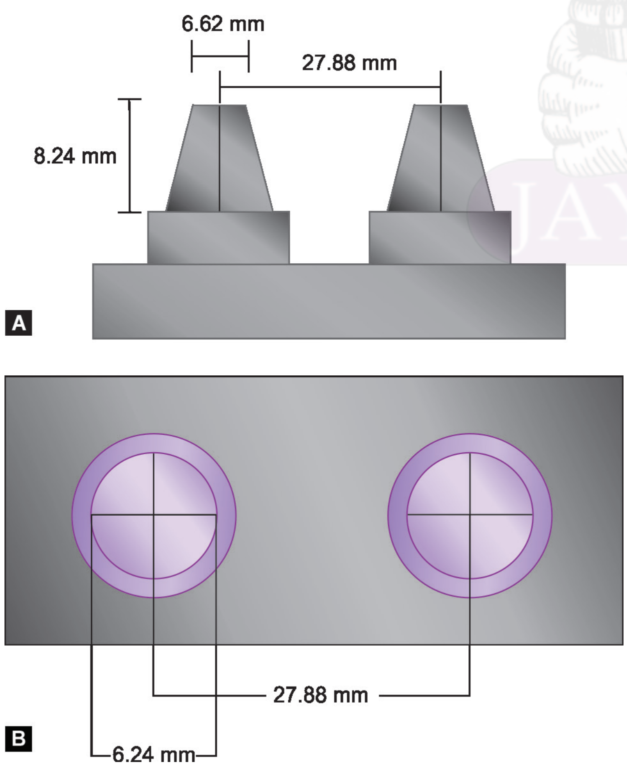
These materials are available in various viscosities: light body (or syringe consistency), monophase (medium body or regular consistency), heavy body (or tray consistency), and very heavy body (or putty consistency). The different viscosities of these materials allow them to be used in two-impression techniques: (1) single step and (2) dual step. The single-step impression technique includes one-step putty/light-body and monophase. Monophase material itself records the finer details. These monophase materials avoid the need for a double mix. The availability of monophase addition silicone impression materials is partly an attempt to acquire some of the positive qualities of polyether materials, such as the hydrophilic properties and ease of use. The dual-step technique includes two-step putty/light body, two-step heavy/light body, and two-step medium/light body.[6,7] All these impression techniques affect the dimensional precision of stone models in a different manner.

Hence, the purpose of the study was to evaluate the dimensional precision of two different brands of addition silicone impression materials using the three impression techniques, i.e., monophase, one-step putty/light body, and two-step putty/light body.

Materials and Methods

The study was conducted at the Department of Prosthodontics, Surendera Dental College and Research Institute, Sriganganagar, Rajasthan, India. A stainless steel die with a brass base containing two complete crowns, tapered abutment preparations labeled as 1 and 2, was fabricated (8.24 mm in height and 6.62 mm diameter, with a 27.88-mm distance between the central points of the two abutments). On the occlusal aspect, each of the abutments was provided with a cross mark to calculate the inter-abutment distance (Figs 1 and 2). It was then used as the master model for the comparison of the impression techniques and impression materials in this study.



Figs 1A and B: (A) Stainless steel die; (B) Occlusal view

Materials Used in the Study

- Virtual addition silicone putty impression material (Ivoclar Vivadent—clinical)
- Aquasil addition silicone putty impression material (Dentsply Sirona)
- Virtual monophase medium body addition silicone impression material (Ivoclar Vivadent—clinical)
- Aquasil ultra monophase medium body addition silicone impression material (Dentsply Caulk)
- Virtual light body addition silicone impression material (Ivoclar Vivadent—clinical)
- Aquasil light body addition silicone impression material (Dentsply Sirona)

A total of 240 samples, 80 in each group, were prepared with two different brands of addition silicone impression materials from the die:

- Group I: $n = 80$ (monophase)
- Group Ia: 40 samples made using Aquasil monophase medium body addition silicone
- Group Ib: 40 samples made using Virtual monophase medium body addition silicone
- Group II: $n = 80$ (one-step technique)
- Group IIa: 40 samples made using Aquasil putty-light body addition silicone
- Group IIb: 40 samples made using Virtual putty-light body addition silicone
- Group III: $n = 80$ (two-step technique)
- Group IIIa: 40 samples made using Aquasil putty-light body addition silicone
- Group IIIb: 40 samples made using Virtual putty-light body addition silicone

Method of Data Evaluation

Impressions were made on the stainless steel die with above-mentioned techniques and materials (Figs 3 and 4). For making the impressions with group I material, acrylic resin custom trays were fabricated. These trays were fabricated by adapting a two-sheet thickness wax spacer on the stainless steel die. For impressions of groups II and III, stock trays were used. The group II impressions were made using simultaneous use of putty and light body. The group III impressions were made using the cellophane sheet spacer having a thickness of 25–40 microns. The storage time for the impressions was 1 hour before pouring into type IV-improved stone (Figs 5 and 6). The impressions were stored at the room temperature. The measurements made on the casts were the following: the diameter of abutment number 1, the height of abutment number 1, and the distance between the centers of the abutments. To calculate the inter-abutment distance, each abutment was provided with a cross mark on its surface and then the inter-abutment distance was determined from the centers of the cross marks of both the abutments. All of these measurements were made with Traveler's microscope and compared with the dimensions of the stainless steel die. The stone casts were measured 48 hours after retrieval from the impressions; during this period, they were stored in air-tight containers at the room temperature.

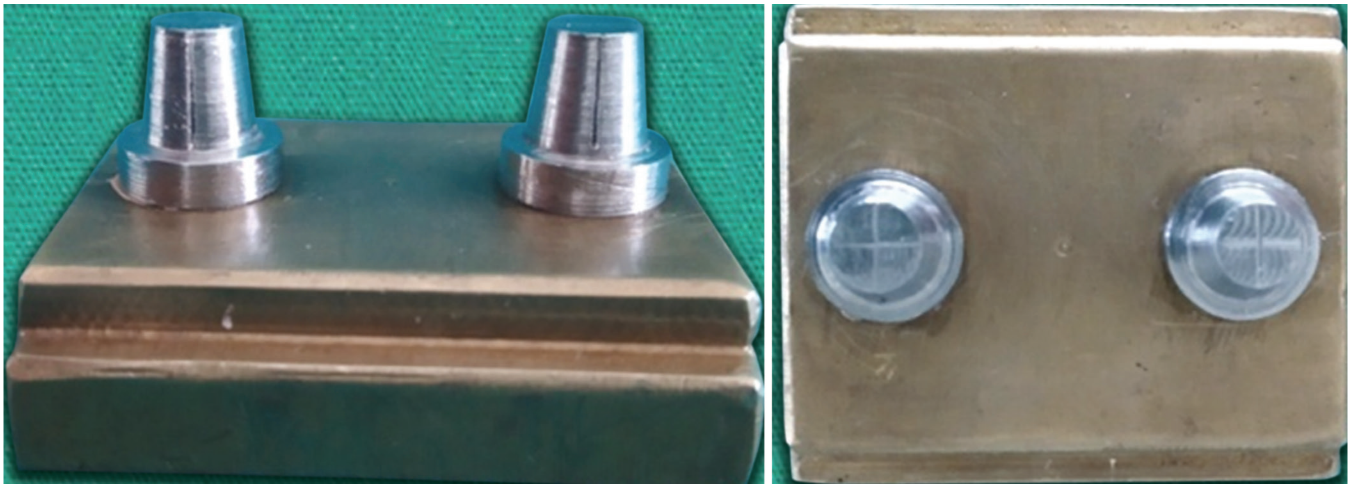
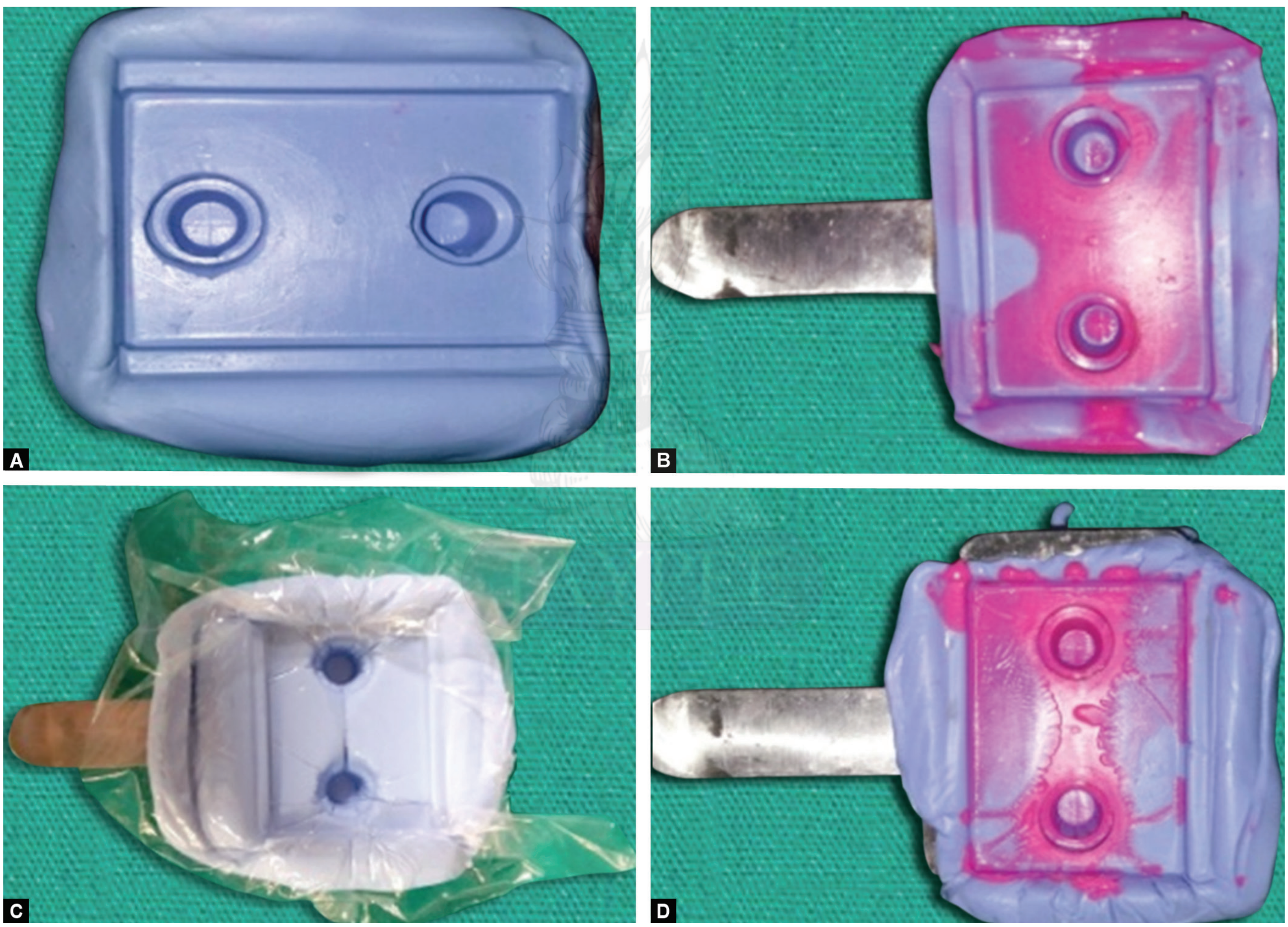


Fig. 2: Master die

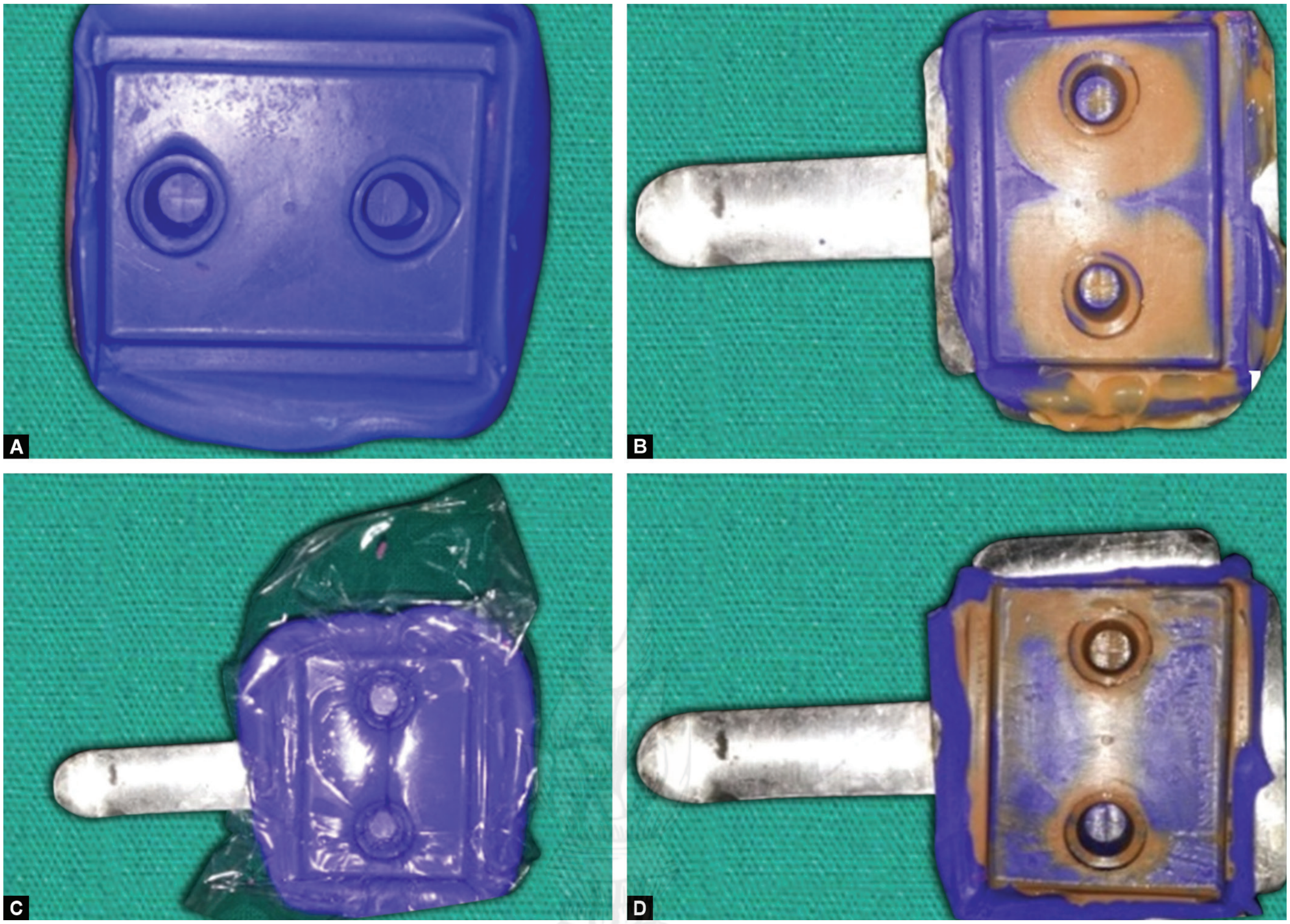


Figs 3A to D: Impressions of Aquasil polyvinyl siloxane; (A) Monophase technique; (B) One-step technique; (C) Two-step technique (with spacer); (D) Two-step technique (light body reline after removing spacer)

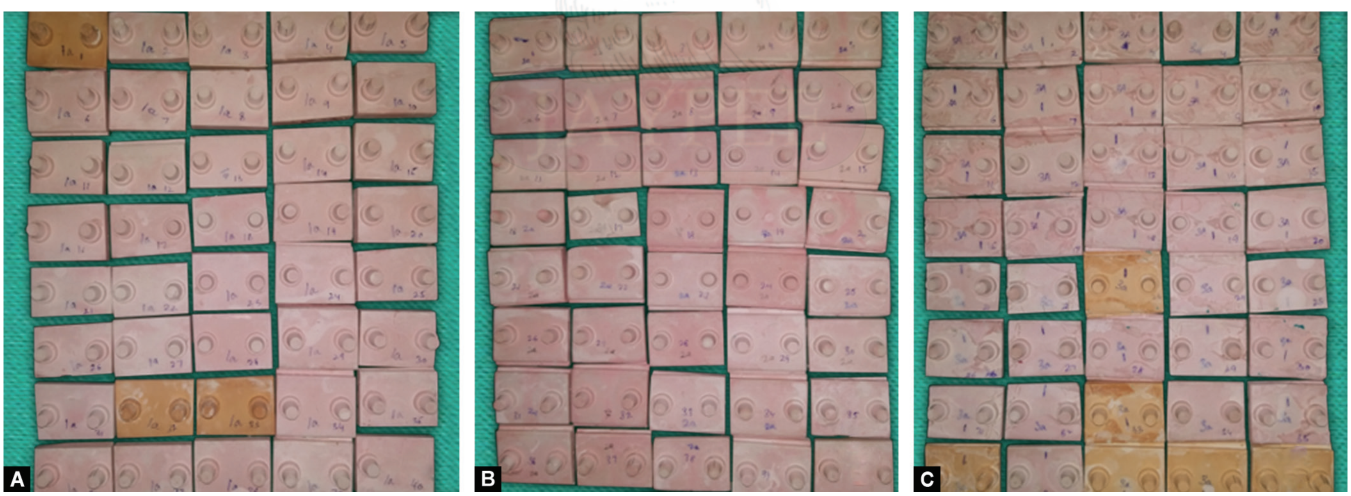
Observations and Results

Results were statistically analyzed using the SPSS 22. A significant difference among the groups was tested using the analysis of variance test, Kruskall–Wallis test, and unpaired *t* test. The level of *p* value was set at <0.05.

In Table 1, it was seen that the mean height and the mean width were the highest in the monophase (Aquasil) and the lowest in the two-step technique (Aquasil) and this difference was statistically insignificant. But the mean inter-abutment distance was the highest in the two-step technique (Aquasil) and the



Figs 4A to D: Impressions of Virtual polyvinyl siloxane; (A) Monophase technique; (B) One-step technique; (C) Two-step technique (with spacer); (D) Two-step technique (light body reline after removing spacer)

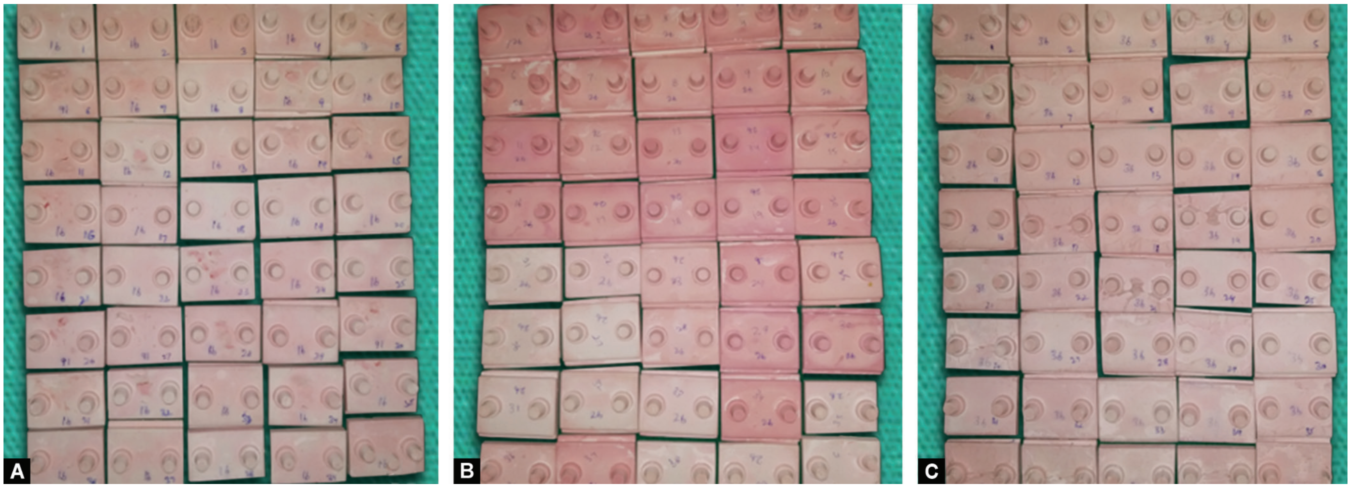


Figs 5A to C: Stone models of Aquasil polyvinyl siloxane impressions; (A) Monophase technique; (B) One-step technique; (C) Two-step technique

lowest in monophase technique (Aquasil) and this difference was statistically significant.

Table 2 displays that the mean height and the mean width was the highest in the monophase (Virtual) and the lowest in the two-step technique (Virtual) and this difference was statistically insignificant. But the mean inter-abutment distance was the highest in the two-step technique (Virtual) and the lowest in the monophase technique (Virtual) and this difference was statistically significant.

Table 3, on comparison with the master model, shows that the mean height difference was minimum in the two-step technique (Aquasil) and the two-step technique (Virtual) and was statistically



Figs 6A to C: Stone models of Virtual polyvinyl siloxane impressions; (A) Monophase technique; (B) One-step technique; (C) Two-step technique

Table 1: Comparison of the dimensional accuracy using the monophase, one-step, and two-step putty/light body impression techniques (Aquasil)

	Height[@]		*Width*[@]		*Inter-abutment distance*[@]	
Group	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Ia: Monophase	8.45[a]	0.26	6.74[a]	0.16	27.62[a]	0.24
IIa: one-step technique	8.39[b]	0.26	6.70[a]	0.18	27.73[b]	0.35
IIIa: two-step technique	8.31[a]	0.35	6.67[a]	0.19	27.85[a]	0.26
ANOVA test	2.99		1.57		3.89	
p value	0.05		0.21		0.02*	

[@], Kruskall Wallis test; Values with same alphabets indicate statistically significant difference as $p < 0.05$; [*], statistically significant

Table 2: Comparison of the dimensional accuracy using the monophase, one-step, and two-step putty/light body impression techniques (Virtual)

	Height		*Width*		*Inter-abutment distance*	
Group	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Ib: Monophase	8.48[a]	0.29	6.76[a]	0.16	27.59[a]	0.25
IIb:one-step technique	8.42[b]	0.24	6.71[a]	0.21	27.70[b]	0.55
IIIb: two-step technique	8.34[a]	0.22	6.69[a]	0.29	27.82[a]	0.36
ANOVA test	3.11		1.42		4.73	
p value	0.05		0.25		0.01*	

Values with same alphabets indicate statistically significant difference as $p < 0.05$

insignificant. The mean height difference was maximum in the monophase technique (Aquasil) and the monophase technique (Virtual) and was statistically significant.

In Table 4, on comparison with the master model, it was shown that the mean width difference was minimum in the two-step technique (Aquasil) and the two-step technique (Virtual) and was statistically insignificant. The mean width difference was maximum in the monophase technique (Aquasil) and the monophase technique (Virtual) and was statistically significant.

Table 5, on comparison with the master model, shows that the mean inter-abutment distance difference was minimum in the two-step technique (Aquasil) and the two-step technique (Virtual) and

Table 3: Comparison of the mean height using the monophase, one-step, and two-step putty/light body impression techniques of Virtual and Aquasil with the master model

Master model	*Group*	*Mean difference*	*t test*	*p value*
8.24	Ia	−0.21	5.11	<0.01*
	IIa	−0.15	3.65	<0.01*
	IIIa	−0.07	1.77	0.09
	Ib	−0.24	5.48	<0.01*
	IIb	−0.18	5.04	<0.01*
	IIIb	−0.10	1.81	0.07

Table 4: Comparison of the mean width using the monophase, one-step, and two-step putty/light body impression techniques of Virtual and Aquasil with the master model

Master model	*Group*	*Mean difference*	*t test*	*p value*
6.62	Ia	−0.12	4.74	<0.01*
	IIa	−0.08	2.81	0.006*
	IIIa	−0.05	1.66	0.1
	Ib	−0.14	5.53	<0.01*
	IIb	−0.09	2.71	0.008*
	IIIb	−0.07	1.53	0.13

Table 5: Comparison of the mean inter-abutment distance using the monophase, one-step, and two-step putty/light body impression techniques of Virtual and Aquasil with the master model

Master model	*Group*	*Mean difference*	*t test*	*p value*
27.88	Ia	0.26	7.16	<0.01*
	IIa	0.15	2.71	0.008*
	IIIa	0.06	1.05	0.29
	Ib	0.29	7.58	<0.01*
	IIb	0.18	2.07	0.04*
	IIIb	0.06	0.73	0.47

was statistically insignificant. The mean inter-abutment distance difference was maximum in the monophase technique (Aquasil) and the monophase technique (Virtual) and was statistically significant.

Table 6 compares all the three techniques of both the materials. It was seen that the results of the monophase, one-step, and two-step putty/wash impression techniques of Aquasil and Virtual were statistically insignificant.

From the above observations, it was found that the two-step putty-light body impression technique produced the most accurate results in terms of the resultant casts. Out of the two different brands, Aquasil produced more fare results.

Discussion

In this study, the precision of various impression techniques using two different brands of addition silicone materials was investigated.

The monophase technique is the easiest to perform, but it has been reported to be the worst in terms of dimensional accuracy. According to a study given by Millar et al.,[7] various surface defects were reported, as compared to both the one-step and two-step putty/light-body techniques, due to the increased viscosity and decreased flow of the material used. In the present study, monophase consistency of both the addition silicone materials showed greatest dimensional variations from the standard dimensions of the stainless steel model.

Because of the comparatively high-viscous monophase material, their injection onto the preparation was more difficult to control. This may have made the placement less accurate and so incorporated voids. There are advantages in the use of a monophase material in terms of reduced mixing, which may, in turn, reduce wastage and avoid the additional clinical time. However, any cost saving in this respect would need to be balanced against the greater volume required to fill a stock tray and the need to retake impressions as a result of unacceptable voids. So, to decrease the wastage of material and to avoid the more number of surface voids, custom trays were used. However, custom trays require additional laboratory time for their fabrication but simultaneously decrease the more number of surface defects and also provide material economy. Monophase addition silicones may also offer further benefits such as higher tear strengths.[8]

In the present study, the putty/light-body impression technique provided more accurate results as compared to the monophase technique.

According to a study conducted by Franco et al.,[9] delay in pouring will allow the material to recover elastically and release of by-products that can influence the accuracy of the stone models, but the delay period should not be too long, otherwise distortions in the impression will occur. So, considering that the impression is a time-dependent procedure, the storage time for all impressions was 1 hour before pouring into the type IV-improved stone.[10]

According to the literature, the single-step technique with vinyl polysiloxanes leads to very accurate impressions. The one-step technique is quite simple, cost effective, less time consuming, and saves the impression material.[11]

But there are several disadvantages of this technique. First, there is absolutely no control of bulk. Moreover, in most situations, parts of the prepared teeth, including margins, are duplicated with putty instead of the syringe. More bubbles are produced and included in the set impression with this technique. Chee and Donovan[4] found sometimes that there are occasional ledges at the junction of the putty and wash material. Another difficulty with the single-step technique is that the light body gets displaced by putty. One more disadvantage is that, by mixing the putty material at the same time as the syringe material, the setting distortion of the putty is included in the overall distortion of the impression. Although this distortion is relatively small, it is desirable to eliminate it if possible.[12]

In this study, the single-step putty/wash impression technique showed more precise results in comparison to the monophase technique for both the materials. But due to its various disadvantages, this technique did not produce as accurate dies as compared to the two-step impression technique. So, in the present study, the two-step impression technique provided the best results, i.e., maximum accurate dies in comparison to the measurements of the master model.

In the two-step technique, the putty material is used for a preliminary impression, while the final impression is performed with a light body material. Even though the two-step technique has been widely adopted and can offer good accuracy, some problems may be experimented with this technique, such as dimensional changes, extra chairside time, and need of extra material. In 2011, Franco et al. conducted a study in which he proposed different alternatives to minimize the discrepancies resulting from impression taking. Relief of the preliminary impression can be provided in the form of die spacers and a plastic sheet to produce adequate space for the wash material to flow in the two-step technique.[11]

In this study also, the cellophane sheet was used as a spacer for the adequate thickness of light body material in the two-step putty/wash technique.

Table 6: Comparison of the dimensional accuracy of Aquasil and Virtual using the monophase, one-step, and two-step putty/light body impression techniques

	Height[@]		*Width*[@]		*Inter-abutment distance*[@]	
Group	*t test*	*p value*	*t test*	*p value*	*t test*	*p value*
Ia vs Ib	0.49	0.63	0.56	0.58	0.55	0.59
IIa vs IIb	0.54	0.59	0.23	0.82	0.29	0.77
IIIa vs IIIb	0.46	0.65	0.37	0.72	0.43	0.67

[@], Kruskall Wallis test

Least dimensional inaccuracies have been observed in stone models when relief is provided in the preliminary impression for the two-step technique, with similar results to dies acquired from the single-step technique. The two-step technique overcomes the problems of the single-step technique, but sometimes, it leads to the formation of an occlusal step on adjacent teeth.[13,14]

In the present study, in all the three techniques, larger dimensions were observed for height and width for both the materials (Aquasil and Virtual) when evaluated with the master model. This observation may also be explained by an expansion of the stone material, although the casts were measured 48 hours after the retrieval from the impression. But dimensions of the inter-abutment distance were observed smaller as compared to the stainless steel model. This finding could be attributed to polymerization shrinkage with time.

The monophase and one-step techniques showed fairly similar results for each dimension, the two-step technique produced more accurate results. In the present *in vitro* study, we can derive an inference that the impression technique can be an important factor in determining the precision of impressions.

In the present study, out of the two addition silicone impression materials, Aquasil displayed the minimal dimensional changes as compared to Virtual.

Limitations of the Study

Greater dimensions were observed for height and width and smaller dimensions were observed for the inter-abutment distance of both the materials as compared to the stainless steel model. It may be due to the expansion of the die stone in which the casts were made or due to the polymerization shrinkage of the putty material.[15] But this study did not explain about the expansion and shrinkage pattern of the stone casts and the putty material. In this study, for the two-step wash impression technique, the cellophane sheet was used as a relief for light-body material, having a thickness of 25–40 microns. However, Nissan et al.[13] in their study stated that for a two-step putty/wash technique, a minimum spacer thickness of 1–2 mm provides more accurate dies as compared to the spacer thickness of a few microns. Wash thickness greater than 2 mm created larger distortions.

Clinical Significance

Accurate reproduction of the prepared tooth is of great clinical importance in the fabrication of fixed dental prosthesis. Inaccuracies in the replication process will ultimately have an adverse effect on the fit and adaptation of the final restoration. So to achieve proper marginal adaptation and avoid dimensional changes in the castings and final prosthesis, adequate impression technique and impression material are of utmost importance.

Conclusion

The following conclusion can be drawn:

- The monophase technique was the least accurate in every dimension considered.
- The one-step technique was more accurate in comparison to monophase, but less accurate than the two-step technique.
- The two-step technique was found to be the most accurate when compared with the master model.
- Casts obtained from the Aquasil impression material were more accurate as compared to the casts obtained from the Virtual impression material.

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