




Article

Accuracy of Master Casts Generated Using Conventional and Digital Impression Modalities: Part 1—The Half-Arch Dimension

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Abstract: Accurate impression-making is considered a vital step in the fabrication of fixed dental prostheses. There is a paucity of studies that compare the casts generated by various impression materials and techniques that are commonly used for the fabrication of provisional and definitive fixed prostheses. The aim of this study is to compare the accuracy of casts obtained using conventional impression and digital impression techniques. Thirty impressions were made for the typodont model (10 impressions each of polyvinyl siloxane, alginate, and alginate alternative materials). Ten digital models were printed from the same model using a TRIOS-3 3Shape intraoral scanner. Accuracy was assessed by measuring four dimensions (horizontal anteroposterior straight, horizontal anteroposterior curved, horizontal cross-arch, and vertical). A one-way ANOVA and Tukey's test ($\alpha = 0.05$) were used to analyze data. A statistically significant difference in the four dimensions of the stone casts and digital models was observed among the four groups (exception: between alginate alternative and 2-step putty–light body impression in the horizontal anteroposterior straight, horizontal anteroposterior curved, and horizontal cross-arch dimensions; between alginate and alginate alternative in the horizontal anteroposterior curved dimension; between alginate and 2-step putty–light body impression in the horizontal anteroposterior curved dimension; and between alginate alternative and digital in the vertical dimension). Polyvinyl siloxane had the highest accuracy compared to casts obtained from other impression materials and digital impressions.

Keywords: accuracy; alginate; impression; intraoral scanner; polyvinyl siloxane; digital impression; intraoral scanner

1. Introduction

Dental prosthetic rehabilitations are characterized by a series of ordered clinical and laboratory steps, during which several types of impression materials and techniques are necessary [1]. Accurate impression-making is considered a vital step in the fabrication of fixed dental prostheses. The current impression materials available for fixed prosthodontic procedures, including polyvinyl siloxanes and polyether, offer an excellent reproduction of surface details of the tooth preparations, as demonstrated by clinical observation and scientific evidence [2–6].

A common technique for making impressions with polyvinyl siloxanes is the putty–light body impression technique. Two different techniques are commonly used: the

one-step and two-step putty–light body impression techniques. The two-step putty–light body technique has been reported to be more accurate than the one-step technique. In the two-step putty–light body technique, there is a uniform space for the light body material to polymerize with minimal shrinkage, and the details are recorded by the light body material only [7–9].

The conventional dental impression technique has many advantages. It is a well-known, relatively simple, and highly accurate technique that requires minimal and simple equipment [10]. However, conventional impressions involve many steps, such as tray selection, application of tray adhesives, type of impression material and technique, disinfection, shipping to a dental laboratory, and pouring the impression with dental stone to prepare the working cast and dies [10,11]. Since this procedure is highly technique-sensitive, inaccuracies in any of these steps can lead to distortion of the master model, resulting in errors in the final dental prosthesis. Therefore, each step must be performed as precisely as possible.

The concept of digital impressions using an intraoral scanner (IOS) has been employed in dentistry since the 1980s, and its use instead of conventional impression techniques has been rapidly increasing for the fabrication of fixed dental prostheses [12]. Digital impression technology is believed to potentially solve the problems and challenges of conventional impressions, is easier to use by the clinician, and is highly accepted by patients [10,11]. Impression trays are not involved in digital impression-taking, which helps overcome the problems related to improper tray selection and separation of the material from the tray. Delay and improper pouring of conventional impressions are common procedures, leading to distortion of impressions [11].

A previous study measured the accessible marginal inaccuracy and the internal fit to evaluate the precision of crowns fabricated using conventional and digital impressions and reported that crowns fabricated using digital impressions were as accurate as those fabricated using conventional impressions [13]. In addition, many researchers have found that the marginal adaptation of all-ceramic crowns fabricated using digital impressions is better than the marginal adaptation of all-ceramic crowns using conventional impressions [14–16]. In contrast, other studies reported no significant difference between the marginal adaptation and the internal fit of all-ceramic crowns and short fixed partial dentures using digital versus conventional impression techniques [17,18].

The previous study evaluated the impression accuracy of quadrant impressions and found that the precision of digital quadrant impressions was comparable to that of conventional methods; however, the precision differed significantly between the digital impression systems [19].

To the best of the authors' knowledge, this is the first study that compares the casts generated by several impression materials and techniques commonly used to fabricate provisional and definitive fixed prostheses.

The purpose of this study was to compare conventional impression (putty and light body consistencies polyvinyl siloxane [PVS], alginate [ALG], and vinyl polysiloxane based alginate alternative [AA]) and digital impression techniques in terms of accuracy, dimensional stability, and ability to produce clinically acceptable casts. This study examined the following two null hypotheses: (1) there will be no statistically significant differences in accuracy between casts made by the two impression modalities and the typodont master model at each of the four locations (horizontal straight [HS], horizontal curved [HC], horizontal cross-arch [HCA], and vertical [V]), and (2) there will be no statistically significant differences in dimensions measured at each of the four locations between the casts generated using the conventional and digital impression techniques.

2. Materials and Methods

2.1. Materials

Materials included in the present study are (1) a maxillary typodont master model (AG-3 Standard Typodont, Practicon, Greenville, NC, USA) to simulate clinical scenarios of

the maxillary arch with missing teeth (1.2, 1.4, 1.6); (2) putty and light body consistencies of PVS impression materials (Putty: Express STD, 3M ESPE, Seefeld, Germany, Batch No.: NA77786. Light body: Express, 3M ESPE, Seefeld, Germany, Batch No.: N653902) with the recommended tray adhesive; (3) Alginate (Kromopan, Lascod, Florence, Italy); and (4) alginate alternative impression materials (Maxill, Cortland, OH, USA) with the recommended tray adhesive.

2.2. Preparation of the Typodont Master Model

A standard all-ceramic preparation was generated in the typodont model using a milling machine (customized dental surveyor with attached high-speed handpiece) according to the following guidelines:

- Incisal/occlusal reduction: 2 mm incisal reduction for anterior teeth. 1.5–2.0 mm occlusal reduction for posterior teeth.
- Axial reduction: 1.2–1.4 mm axial reduction (facial/buccal, lingual/palatal, mesial, and distal).
- Shoulder width: A 1 mm circumferential shoulder was prepared for all the anterior and posterior teeth.
- The preparation was smoothed and free of any sharp points or line angles.
- The typodont master model received a standard all-ceramic preparation for teeth #1.1, 1.3, 1.5, and 1.7; missing teeth #1.2, 1.4, and 1.6.

Parallel indentations were milled on the prepared teeth (1.7, 1.5, 1.1, and 2.7) on the typodont master model and used as reference points for the horizontal measurements (horizontal straight [1.7, 1.5], horizontal curved [1.7, 1.1], and horizontal cross-arch [1.7, 2.7]) (Figure 1A). Additionally, parallel occlusal and cervical reference points were milled on prepared tooth #1.3 and used for the vertical measurements (Figure 1B).

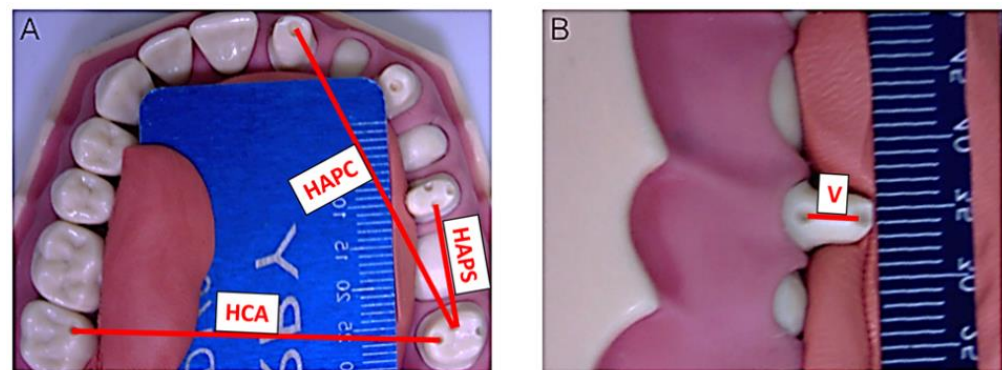


Figure 1. Master model prepared with prepared teeth and index points for (A) horizontal and (B) vertical measurements, in which positioning of the ruler was performed for digital calibration. HAPS, horizontal anteroposterior straight; HAPC, horizontal anteroposterior curved; HCA, horizontal cross-arch; V, vertical.

2.3. Fabrication of Casts Using the Conventional Impression Technique

Ten metallic rim-lock-perforated maxillary stock trays (size six) were used. To standardize the stability of the typodont teeth before impression-making, cyanoacrylate adhesive resin was used at the same time as screwing the typodont teeth in the master model. Ten impressions were made for each group using the PVS impression material with the two-step putty–light body impression (PVS-2) technique (using a polyethylene spacer), ALG, and AA impression materials. The impressions were made according to the technique and manufacturer’s recommendations; they were subsequently poured into type IV die stone (Elite Rock, Badia Polesine, Zhermack Rovigo, Italy, No.: 0000310633), which was mixed under a vacuum mixture (Mix-R, Dentalfarm, Torino, Italy, A5502) and poured on a vibrator (Plaster Vibrator A0120 VIT, Dentalfarm, Torino, Italy, A0126) following the manufacturer’s recommendations (Figure 2).

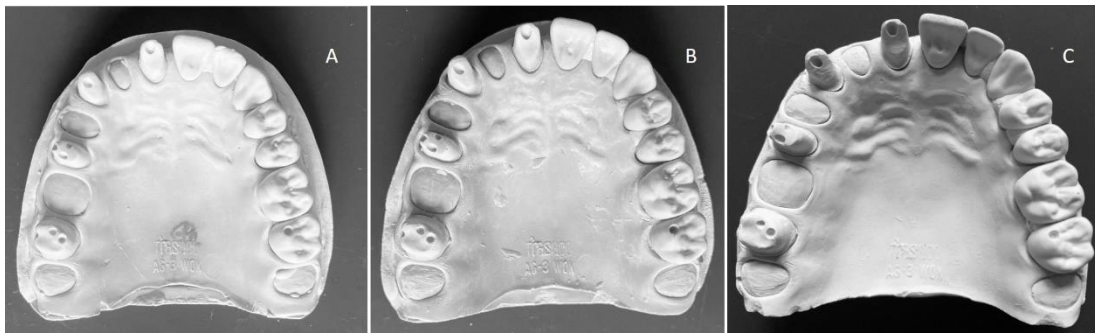


Figure 2. Casts fabricated using the conventional impression techniques. (A) Alginate impression, (B) Alginate Substitute impression and (C) PVS impression.

2.4. Fabrication of Casts Using the Digital Impression Technique

The prepared typodont master model was scanned using a TRIOS-3 3Shape intraoral scanner (Align Technology, San Jose, CA, USA, Model No: S2A-1) and sent to the dental laboratory for three-dimensional (3D) printing of the scanned models using a 3D printing machine (Asiga, Alexandria, Australia; Resin: ASIGA Dental MODEL, LOT No. MO/10259, Asiga Pty Ltd., Alexandria, NSW, Australia). Each typodont master model was scanned ten times according to the manufacturer's instructions (Figure 3A,B). In the dental laboratory, a 3D printing machine was used to print ten models (Figure 4).

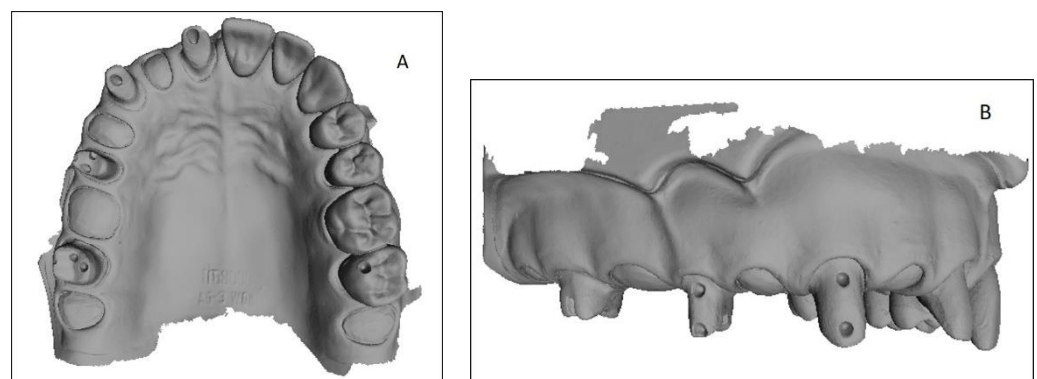


Figure 3. (A,B). Scanned images of prepared typodont master model.



Figure 4. Cast fabricated using digital impression technique and 3D printing.

2.5. Measurements

A computer system consisting of a stereomicroscope with a connected USB CCD camera (Amscope, Irvine, CA, USA), a personal computer, and compatible measurement

software (Version No: 3.7.12924) was used to record the measurements for the horizontal (anteroposterior and cross-arch) and vertical dimensions. Putty indexes were used to maintain the same angulation and distance from the camera. The horizontal and vertical distances on the typodont master models were measured three times for each dimension. The average was calculated and used as the control to compare the four groups of poured stone and the printed master casts. To ensure reproducibility, each cast measurement was repeated three times, and the corresponding mean values were considered as statistical units. The accuracy of casts fabricated by conventional and digital methods was expressed as the percentage deviation from the typodont master model's values.

2.6. Data Analysis

Descriptive statistics were used to calculate the mean and standard deviations. A one-way analysis of variance (ANOVA) was used to assess the significance of the differences in dimensional measurements of the casts generated by conventional and digital impression techniques. Tukey's HSD test was used for pairwise comparisons to determine the differences between the tested subgroups. Moreover, a one-sample t-test was used to analyze the dispersion of the measurements around the fixed values of the typodont master model. Data were processed using the SPSS for Windows, version 21 software (SPSS Inc., Chicago, IL, USA). For all the statistical analyses, the level of significance was set at $p < 0.05$. In addition, according to the American Dental Association (ADA) specification No. 19, the accuracy of the fabricated casts is expressed as the percentage of deviation from the corresponding typodont master model's values. For each dimension, the difference between the mean value of the cast model (MCM) and the mean value of the typodont master model (MTMM), divided by the mean value of the typodont master model and multiplied by 100, expressed as the percentage of deviation from the typodont master model for each tested subgroup of each dimension was computed as follows:

$$\text{Percentage of deviation} = [(MCM - MTMM)/MTMM] \times 100$$

3. Results

Table 1 and Figure 5 provide descriptive statistics for the stone casts and printed models from the four tested groups (ALG, AA, PVS-2, and DIGITAL) and the typodont master cast in each dimension (horizontal anteroposterior straight [HAPS], horizontal anteroposterior curved [HAPC], horizontal cross-arch [HCA], and vertical [V]).

Table 1. Measurements of stone casts, printed models, and the typodont master model (mm).

Dimension (mm)	Typodont Master Model		ALG		AA		PVS-2		DIGITAL	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HAPS	14.82	0.00	14.91 *	0.08	14.78 *	0.03	14.84	0.05	15.14 *	0.05
HAPC	40.77	0.00	40.67	0.18	40.75	0.08	40.74	0.09	41.11 *	0.08
HCA	44.52	0.00	44.40 *	0.11	44.74 *	0.07	44.64 *	0.07	44.90 *	0.07
Vertical	4.31	0.00	4.06 *	0.06	4.11 *	0.02	4.26 *	0.02	4.12 *	0.02

* Significant compared to the typodont master model at $p \leq 0.05$. SD, standard deviation; ALG, alginate; AA, alginate alternative; PVS-2, two-step putty-light body polyvinyl siloxane; HAPS, horizontal anteroposterior straight; HAPC, horizontal anteroposterior curved; HCA, horizontal cross-arch.

Testing of the first null hypothesis required four comparisons (ALG vs. typodont master model, AA vs. typodont master model, PVS-2 vs. typodont master model, and DIGITAL vs. typodont master model) for each dimension (Table 2). Pairwise comparisons were performed using t-tests; these revealed that the HAPS, HAPC, HCA, and V dimensions on the typodont master model and the stone casts and digital models were significantly different ($p < 0.001$), except for PVS-2 in the HAPS and HAPC dimensions ($p > 0.05$) and ALG and AA in the HAPC dimension ($p > 0.05$).

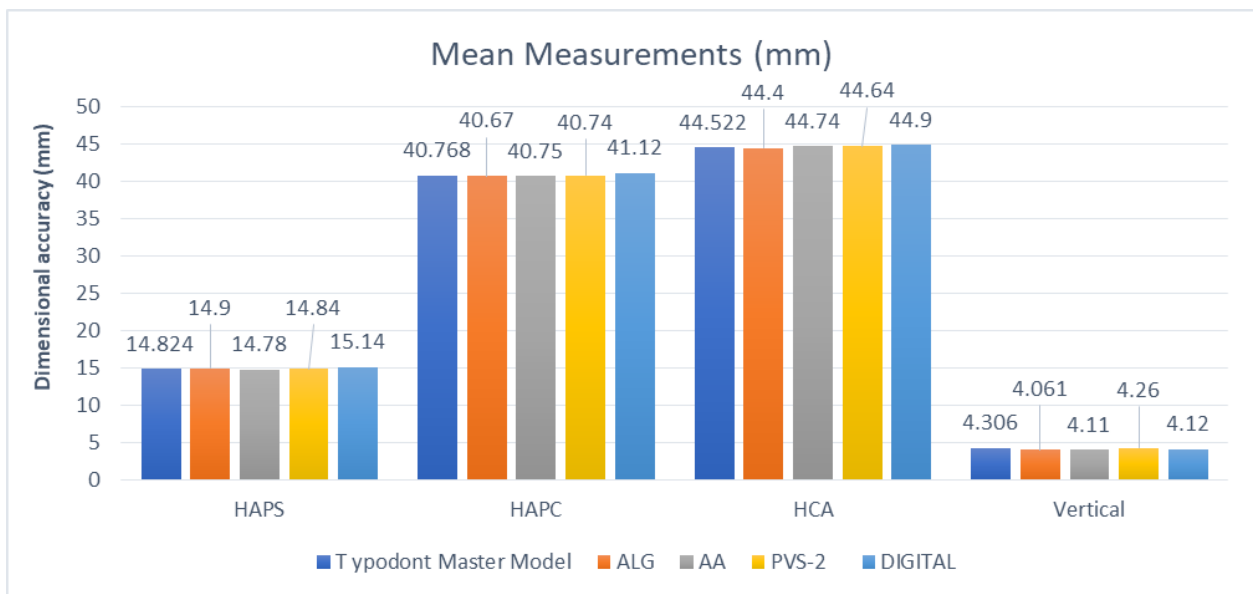


Figure 5. Measurements of stone casts, printed models, and the typodont master model (mm).

Table 2. One sample *t*-test results for the dispersion of measurements around the test values (typodont master cast measurements).

Horizontal Anteroposterior Straight Test Value = 14.82			
	t (df)	Mean diff. (95% CI)	<i>p</i>
ALG	3.24 (9)	0.08 (0.02, 0.14)	0.010
AA	−3.88 (9)	−0.04 (−0.07, −0.02)	0.004
PVS-2	0.76 (9)	0.01 (−0.02, 0.05)	0.470
DIGITAL	18.61 (9)	0.32 (0.28, 0.35)	<0.001
Horizontal Anteroposterior Curved Test Value = 40.77			
ALG	−1.74 (9)	−0.10 (−0.23, 0.03)	0.116
AA	−0.59 (9)	−0.02 (−0.07, 0.04)	0.570
PVS-2	−1.03 (9)	−0.03 (−0.10, 0.04)	0.331
DIGITAL	13.60 (9)	0.33 (0.28, 0.40)	<0.001
Cross-Arch Test Value = 44.52			
ALG	−3.39 (9)	−0.12 (−0.20, −0.04)	0.008
AA	9.97 (9)	0.21 (0.16, 0.26)	<0.001
PVS-2	5.26 (9)	0.12 (0.07, 0.17)	0.001
DIGITAL	17.84 (9)	0.38 (0.33, 0.43)	<0.001
Vertical Test Value = 4.31			
ALG	−13.30 (9)	−0.25 (−0.29, −0.20)	<0.001
AA	−28.41 (9)	−0.20 (−0.21, −0.18)	<0.001
PVS-2	−7.02 (9)	−0.06 (−0.07, −0.03)	<0.001
DIGITAL	−26.20 (9)	−0.19 (−0.21, −0.17)	<0.001

ALG, alginate; AA, alginate alternative; PVS-2, two-step putty–light body polyvinyl siloxane; df, degrees of freedom.

In general, all the measurements of stone casts produced by the PVS-2 impression material were lower than those for the master cast in the HAPC ($p > 0.05$) and V ($p < 0.01$) dimensions but were higher than those for the master cast in the HAPS ($p > 0.05$) and

HCA ($p < 0.01$) dimensions. The measurements for the stone casts generated by the ALG impression material were lower than those for the master cast in the HAPC ($p > 0.05$), HCA ($p < 0.001$) and V ($p < 0.001$) dimensions but were higher than those for the master cast ($p < 0.001$) in the HAPS dimension. With the AA impression material, the measurements for the stone casts were lower than those for the master cast in the HAPS ($p < 0.001$), HAPC ($p > 0.05$), and V ($p < 0.001$) dimensions but were higher than those for the master cast ($p < 0.001$) in the HCA dimension. However, the measurements on the digital models were significantly lower than those for the master cast ($p < 0.001$) in the HAPS, HAPC, and V dimensions. However, they were significantly higher than those for the master cast ($p < 0.001$) in the HCA dimension.

To test the second hypothesis, a one-way ANOVA was conducted to examine the differences in the accuracy of the casts made using the three impression materials and the digital system. There was a significant difference in the means in the four dimensions of the location (Table 3).

Table 3. Comparison of dimensional accuracy (mm) between ALG, AA, PVS-2 generated casts and digitally printed models using a one-way ANOVA.

Dimension	Impression	n	Mean	SD	F Statistics (df)	p Value ^a
HAPS	ALG	10	14.91	0.08	79.26 (3.36)	<0.001
	AA	10	14.78	0.04		
	PVS-2	10	14.84	0.05		
	DIGITAL	10	15.14	0.05		
HAPC	ALG	10	40.67	0.18	28.41 (3.36)	<0.001
	AA	10	40.75	0.08		
	PVS-2	10	40.74	0.09		
	DIGITAL	10	41.11	0.08		
HCA	ALG	10	44.40	0.11	65.02 (3.36)	<0.001
	AA	10	44.74	0.07		
	PVS-2	10	44.64	0.07		
	DIGITAL	10	44.90	0.07		
V	ALG	10	4.06	0.06	56.37 (3.36)	<0.001
	AA	10	4.11	0.02		
	PVS-2	10	4.25	0.02		
	DIGITAL	10	4.12	0.02		

^a A one-way ANOVA was used. The significance level was set at 0.05. SD, standard deviation; ALG, alginate; AA, alginate alternative; PVS-2, two-step putty–light body polyvinyl siloxane; HAPS, horizontal anteroposterior straight; HAPC, horizontal anteroposterior curved; HCA, horizontal cross-arch; V, vertical; df, degrees of freedom; ANOVA, analysis of variance.

Further analysis using Tukey’s HSD post hoc test was conducted among the four groups in the four location dimensions (HAPS, HAPC, HCA, and V) (Table 4). A statistically significant difference in the four dimensions (HAPS, HAPC, HCA, and V) of the stone and printed casts were observed among the four groups (ALG, AA, PWAS-2, and DIGITAL) (exception: between AA and PVS-2 in HAPS, HAPC, and HCA dimensions; between ALG and AA in the HAPC dimension; between ALG and PVS-2 in the HAPC dimension; and between AA and DIGITAL in the V dimension). In general, casts made from ALG impression material shrunk in the HAPC, HCA, and V dimensions but expanded in the HAPS dimension. With the AA impression material, the casts showed contraction in the HAPS, HAPC, and V dimensions and expansion in the HCA dimension. Casts made from the PVS-2 impression material contracted in the HAPC and V dimensions but expanded

in the HAPS and HCA dimensions. However, DIGITAL models showed expansion in the HCA dimension and contraction in the HAPS, HAPC, and V dimensions.

Figure 6 shows the percentage of deviations (%) and absolute changes (in μm) in stone cast dimensions from those of the typodont master cast for the three tested groups. The ADA specification No. 19 for elastomeric type I impressions allows a maximum contraction of 0.5% after 24 h [20]. Thus, a clinically significant distortion could be considered as any dimensional change (contraction or expansion) greater than 0.5 percent. For stone casts made using the ALG impression material, Figure 6 shows that the HAPC and HCA measurements did not exceed 0.5 percent in dimensional change. For stone casts made using both AA and PVS-2 impression materials, the only measurement that exceeded 0.5 percent in dimensional change was the V measurement. However, the greatest number of distortions above 0.5 percent (at all dimensional locations) was produced by the digital models.

Table 4. Multiple pairwise comparisons of the accuracy of the three impression materials and digital impression using Tukey's HSD Test.

	Pairwise Comparison	Mean (SD)	Mean Difference	<i>p</i> Value *
HAPS	ALG vs. AA	14.91 (0.08) 14.78 (0.04)	0.13	<0.001 *
	ALG vs. PVS-2	14.91 (0.08) 14.84 (0.05)	0.07	0.04 *
	ALG vs. DIGITAL	14.91 (0.08) 15.14 (0.05)	−0.23	<0.001 *
	AA vs. PVS-2	14.78 (0.04) 14.84 (0.05)	−0.06	0.157
	AA vs. DIGITAL	14.78 (0.04) 15.14 (0.05)	−0.36	<0.001 *
	PVS-2 vs. DIGITAL	14.84 (0.05) 15.14 (0.05)	−0.30	<0.001 *
	HAPC	ALG vs. AA	40.67 (0.18) 40.75 (0.08)	−0.08
ALG vs. PVS-2		40.67 (0.18) 40.74 (0.09)	−0.07	0.528
ALG vs. DIGITAL		40.67 (0.18) 41.11 (0.08)	−0.44	<0.001 *
AA vs. PVS-2		40.75 (0.08) 40.74 (0.09)	0.01	0.991
AA vs. DIGITAL		40.75 (0.08) 41.11 (0.08)	−0.36	<0.001 *
PVS-2 vs. DIGITAL		40.74 (0.09) 41.11 (0.08)	−0.37	<0.001 *
HCA	ALG vs. AA	44.40 (0.11) 44.74 (0.07)	−0.34	<0.001 *
	ALG vs. PVS-2	44.40 (0.11) 44.64 (0.07)	0.24	<0.001 *
	ALG vs. DIGITAL	44.40 (0.11) 44.90 (0.07)	−0.50	<0.001 *
	AA vs. PVS-2	44.74 (0.07) 44.64 (0.07)	0.10	0.067
	AA vs. DIGITAL	44.74 (0.07) 44.90 (0.07)	−0.16	<0.001 *
	PVS-2 vs. DIGITAL	44.64 (0.07) 44.90 (0.07)	−0.26	<0.001 *

Table 4. Cont.

	Pairwise Comparison	Mean (SD)	Mean Difference	<i>p</i> Value *
V	ALG vs. AA	4.06 (0.06) 4.11 (0.02)	−0.05	0.02 *
	ALG vs. PVS-2	4.06 (0.06) 4.25 (0.02)	−0.19	<0.001 *
	ALG vs. DIGITAL	4.06 (0.06) 4.12 (0.02)	−0.06	0.006 *
	AA vs. PVS-2	4.11 (0.02) 4.25 (0.02)	−0.014	<0.001 *
	AA vs. DIGITAL	4.11 (0.02) 4.12 (0.02)	−0.01	0.962
	PVS-2 vs. DIGITAL	4.25 (0.02) 4.12 (0.02)	0.13	<0.001 *

* Indicates that the two means are significantly different according to Tukey's HSD test. SD, standard deviation; ALG, alginate; AA, alginate alternative; HAPS, horizontal anteroposterior straight; HAPC, horizontal anteroposterior curved; HCA, horizontal cross-arch; V, vertical.

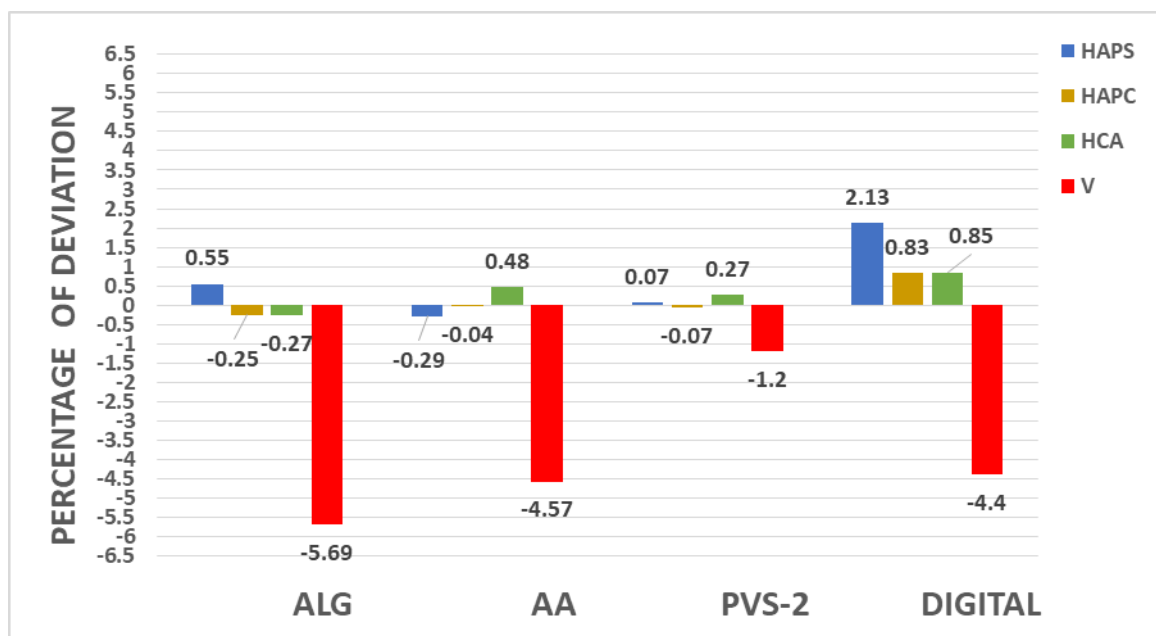


Figure 6. Percentage of deviation from the typodont master cast for impression materials and digital models. ALG, alginate; AA, alginate alternative; PVS-2, two-step putty–light body polyvinyl siloxane; HAPS, horizontal anteroposterior straight; HAPC, horizontal anteroposterior curved; HCA, horizontal cross-arch; V, vertical.

4. Discussion

In prosthodontics, the accuracy of the master cast used for the fabrication of fixed dental prostheses is paramount. The choice and proper manipulation of the final impression material are vital. According to the ADA specification on impression materials, there are specifications to test their accuracy and ability to reproduce fine details using simulated tooth models presenting areas that can be easily measured [21]. Therefore, a typodont master model with half-arch-prepared abutment teeth was used in the present study.

Although variations exist among intra-oral scanners, this study utilized a TRIOS-3 3Shape intra-oral scanner as a representative of the digital scanners used in fixed prosthodontics since it reportedly has the highest precision compared to other scanners [20]. The current study did not use the digital versions of the casts; instead, casts were printed to standardize the groups, to have the same testing conditions, and to avoid any errors,

while measurements were made using a stereomicroscope. The distance between the casts and microscope was standardized, and a ruler was used for calibration using the software.

The discrepancies between stone casts and the master model had positive and negative values; to avoid false results due to the positive and negative values cancelling each other out, the data were converted to absolute values, which has been employed previously by other researchers [22,23].

The die stone casts obtained from PVS-2 presented the highest accuracy in the present study compared to the casts obtained from other impression materials and digital impressions. The best result in the present study was observed for the group using the putty–light body impression technique. This was supported by the findings of similar comparative studies [7,24,25]. This is because in the two-step putty–light body technique, there is uniform space for the light body material to polymerize with minimal shrinkage, and the details are recorded by the light body material only [7–9].

The 3D-printed models obtained from the intraoral scanning digital impression did not exhibit superior accuracy than the stone casts obtained from the conventional impression materials (ALG. AA, PWAD-2). This result was supported by the findings of Ender and Mehl, who found that the local deviations of the full-arch impressions were higher for digital impression systems than for conventional impression methods [26].

The results of this study indicated that stone casts generated using conventional impression and pouring techniques have a higher linear dimensional accuracy than 3D-printed casts, which contradicts the findings reported by recent studies [27,28]. A recent systematic review evaluated the accuracy of 3D-printed models generated by different printing technologies and reported that dimensional variation might exceed 500 μm , especially for stereolithographic technology printers [29]. The 3D printer used in the current study is reported to have a mean discrepancy in the range of $68.27 \pm 43.53 \mu\text{m}$, which is comparable to few other commonly used printers [30]. Such significant variability may be acceptable for diagnostic purposes but not for prosthodontic procedures requiring high accuracy and precision.

In the present study, the accuracy of the die stone casts obtained using AA was comparable to that obtained using PVS-2. This is consistent with many studies that compared the accuracy of AA to elastomeric impression materials and found comparable accuracy due to the fillers that are present. However, they do not have the same stability [21,23].

Although AA was introduced to the dental practice more than two decades ago, it has not been studied extensively in prosthodontic literature [31,32]. The results of this study are in agreement with Kusugal et al. [33], in which AA was found to be more accurate than extended pour ALG in terms of surface details reproduction and dimensional stability. In addition, Faria and their colleagues [23] found that casts generated from addition silicone were more accurate than ALG impression materials. However, a direct comparison between AA, PVS, and 3D-printed casts has not been conducted to date. The results of this study indicated that the accuracy of AA impression-based casts is higher than extended pour ALG, 3D printing, and slightly lower than conventional addition silicone impression material using the putty–light body technique. Therefore, based on the results of this study, AA might be indicated for the fabrication of accurate long-span computer-aided design/computer-aided manufacturing (CAD/CAM) provisional fixed prosthesis and interim partial denture with benefits of the impression's ease of handling and predictable dimensional accuracy, while the putty–light body technique remains the golden standard for accurate fabrication of long-span definitive prosthesis up to the quadrant dimension.

Although the test embodied in the ADA specifications provides good baseline data to compare materials, the testing conditions differ from those encountered during clinical practice. Therefore, future in vivo studies are recommended. Hence, future studies to compare the studied materials and technologies in a clinical setting are indicated.

Clinical significance: for the quadrant dimension, a dentist may consider 2-step putty-wash polyvinyl siloxane because it had the highest accuracy compared to the studied conventional and digital impressions.

5. Conclusions

Overall, this in vitro study showed that the 3M ESPE PVS impression material was the most accurate among the four tested groups. In addition, the Maxill AA showed comparable accuracy to the 3M ESPE PVS impression material. The V dimension measurement was the only measurement of the stone casts produced by both 3M ESPE PVS and Maxill AA impression materials that exceeded 0.5 percent in dimensional change. Lastly, we found that the digital impression made using a TRIOS-3 3Shape intra-oral scanner was the least accurate among the four groups. The greatest number of distortions above 0.5 percent (at all dimensional locations) was produced by the digital models printed using the ASIGA 3D printer.

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