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Original Article

Alginate Substitute as a Promising Impression Material for Dental Implant Restorations: A Comparative In-vitro Study

Mohammed E. Sayed[1], Bandar M. A. AL-Makramani[1,2], Fuad A. Al-Sanabani[1,2], Ali M. Nammazi[1], Alwaleed E. Bakri[1], Mosaab M. Qohal[1]

[1]Department of Prosthetic Dental Sciences, College of Dentistry, Jazan University, Jazan, Saudi Arabia

[2]Department of Restorative Dentistry, College of Dentistry, Sana'a University, Sana'a, Yemen

CORRESPONDING AUTHOR

Mohammed Sayed
Department of Prosthetic Dental Sciences,
Jazan University College of Dentistry, Jazan 45142,
Saudi Arabia.
drsayed203@gmail.com

https://orcid/org/0000-0001-8667-8987

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ABSTRACT

Objective: To compare the accuracy of alginate substitute with polyvinyl siloxane (PVS) impression materials for both single and multiple implant restorations using open- and closed-tray techniques placed unilaterally in a partially edentulous maxillary Typodont model.

Methods: Two maxillary typodont hard models, two impression materials and two impression techniques were used in this study. A total of 80 impressions were made for both models simulating clinical scenario for single and multiple implant restorations, 10 impressions for each subgroup. Accuracy was assessed by measuring three dimensions (Anteroposterior, cross arch and vertical) on stone models obtained from impressions of the typodont models. Each dimension was measured three times and the mean value was calculated. The data were analyzed using independent samples t-test and Mann-Whitney U Test.

Results: In group 1 (single implant), significant differences were found only in the vertical dimension between alginate substitute and monophase PVS impression materials when using an open-tray technique (mean diff.= 0.17; P= 0.003), and between closed- and open-tray techniques when using alginate substitute impression material (mean diff.= -0.24; P= 0.008). In group 2 (multiple implants), significant differences were found only in the horizontal cross-arch and vertical dimensions between open and closed-tray techniques when using alginate substitute impression material (P= 0.049 and P≤ 0.01, respectively).

Conclusion: The results obtained showed that the stone dies fabricated using monophase PVS and alginate substitute impression materials were comparable to those of the typodont models. Overall discrepancies of the monophase PVS were smaller than those of the alginate substitute but not statistically significant.

Keywords: Alginate substitute; Dental implant; Dental impression; Impression technique; Monophase polyvinyl siloxane.

INTRODUCTION

The accuracy of the impression technique is an important factor for the fabrication of passively fitting dental implant prosthesis. Many factors may affect the accuracy of impressions for a dental implant such as impression materials, impression techniques, type of tray, number of implants, distribution of implants, and angulation of abutments or implants.[1-4]

The fabrication of passively fitting implant prosthesis will lead to long-term success of the implant prosthesis.[5] An accurate impression material and technique are essential in recording the intraoral 3-dimensional relationship of implants to produce passively fitting implant prostheses. Therefore, the clinical fit of an implant prosthesis at the implant-abutment connection is directly dependent on the accuracy of the impression procedure and cast fabrication.[6,7] Although having an absolute passive fit is practically impossible, minimizing the misfit to avoid probable difficulties is a commonly accepted goal of prosthetic dental implant procedures.[8]

Advances in dentistry include the introduction of computer-aided design/computer-aided manufacturing (CAD/CAM) technology. This technology allows the fabrication of wide array of implant-supported fixed dental prosthesis ranging from a single crown to full-arch prosthesis. However, due to certain technical and cost factors, CAD/CAM has yet to gain availability.[9] A recent survey study among members of the Swiss Dental Association reported that 23% of studied practices were applying CAD/CAM technology in the daily restorative workflow.[10] In addition, a recent review compared the accuracy of intra-oral scanners with conventional impression techniques in fixed prosthodontics, reported that conventional impression techniques are superior in accuracy, especially for long-span and full arch rehabilitation cases.[11] Therefore, the different conventional impression techniques, used in the fabrication of master cast, remain standard and play a major role in the construction of dental prosthesis to date.[9]

Various implant impression techniques have been used to porduce a final cast that will ensure the correct clinical fit of implant fixed dental prostheses. Open and closed trays techniques, either splinted or non-splinted, are the most commonly used implant impression techniques. Overall, the results are variable and even contradictory.[1,12,13]

Numerous studies have been documented in the literature regarding the accuracy of different impression materials (polyvinyl siloxane, polyether or irreversible hydrocolloid).[12-16] However, there still a lack of consensus in the literature regarding the use of newly introduced silicone-based material, called alginate substitute, for final impression in fixed prosthodontics. In addition, the high cost of conventional elastomeric impression materials presents financial burden on clinicians and therefore patients, especially those who live in low-income countries.

Using alginate substitute as a final impression material will reduce the cost for the clinician and subsequently for the patients. Therefore, the purpose of this in vitro study is to compare the accuracy of two different impression materials (monophase PVS and alginate substitute) as a final impression for both single and three implant restorations using most common impression techniques (open and closed-tray) for single and multiple implants placed unilaterally in a partially edentulous maxillary model. The null hypothesis was that there is a difference in the dimensional accuracy of stone casts fabricated using alginate substitute and monophase PVS impression materials when used for single and multiple implants restorations in a partially edentulous arch.

MATERIALS AND METHODS

Two maxillary typodont hard models (Model A-3, Frasaco GmbH, Tettnang, Germany) were used in this study and modified to simulate final impression procedure for clinical scenarios of maxillary arch with single or multiple endosseous implants. The socket of tooth #3 was used to insert an analog to represent single implant group, while the sockets of teeth #3, 5 and 8 were used to insert three implant analogs to represent multiple implants group for 6-units implant supported FPD (Figure 1& 2).

A total 84 Vitane impression posts and analogs (Vitane, Strasbourg, France) were utilized to conduct this study, in which 80 of each (40 closed-tray, 40 open-tray posts and 80 analogs) were used to represent the study samples, while 4 analogs were used to represent the master models and 4 closed-tray impression posts were used for measurement. The posterior analogs in the single and multiple implants groups were placed parallel to adjacent teeth and perpendicular to the common occlusal plane, while the anterior analog in the multiple implants group was placed in an angle parallel to the anterior teeth in the most ideal clinical position.

The sockets of predetermined sites were prepared to fit the entire length of analogs. Then, the models were mounted on a dental surveyor (Ney Dental Surveyor; Dentsply, Ballaigues, Switzerland) and occlusal plane was oriented parallel to horizon.

The analogs were mounted on the surveyor (Ney Dental Surveyor; Dentsply, Ballaigues, Switzerland) with the help of open-tray impression post connected to the adjustable vertical arm of the surveyor. The sockets were adjusted to fit the analogs' entire length. The vertical arm was lowered, fixated and auto-polymerizing acrylic resin (GC pattern resin, GC Corp, Tokyo, Japan) was used to mount analogs within their respective sockets. The resin was allowed to set overnight to ensure complete setting.

A total of 80 custom trays prepared of which 40 were used for closed tray and 40 for open tray impression techniques. To facilitate the fabrication of custom trays, wax spacer of 4mm thickness was adapted over the teeth and closed tray impression posts, while for open tray the top part of the long screw was exposed through wax to allow accessibility upon impression retrieval. The land area of the main model was planned as vertical stop to control the amount of material and tray position upon impression making. The master models were duplicated using duplicating silicone (Dupliflex-22, Protechno, Vilamalla, Girona, Spain), and stone models were poured in type IV stone (Elite Model, Zhermack, Badia Polesine, Rovigo, Italy) to be used for the fabrication of the custom trays. The trays were fabricated using light-cure acrylic resin sheets (Meditray, Promedica Dental Material GmbH, Neumunster, Germany), which were molded according to the desired tray design, and cured in laboratory light curing unit (Triad 2000, Dentsply, Milford, DE, USA).

According to the number of implants, the study sample divided into two groups; group I (single implant) and group II (three implants) with 40 samples in each group. According to the impression materials that were used, the two main groups were subdivided into two subgroups with 20 samples in each subgroup using regular-set alginate substitute (Defend, Mydent International, Hauppauge, NY, USA) and regular-set monophase PVS impression materials (Defend, Mydent International, Hauppauge, NY, USA). Furthermore, each subgroup was divided into two subgroups according to the impression technique (open and closed tray) with 10 samples in each subgroup. The sample distribution is summarized in Figure 3.

In this study a total of 80 impressions were made using alginate substitute and monophase PVS impression materials according to the technique and manufacturer recommendations. The impressions were poured in type IV die stone (Elite Rock, Badia Polesine, Zhermack Rovigo, Italy), which was mixed under vacuum mixture (Mix-R, Dentalfarm, Torino, Italy) and poured on vibrator (Plaster Vibrator A0120 VIT, Dentalfarm, Torino, Italy) following manufacturer recommendations.

Measurements

Measurement was performed on a mirror image generated by the stereomicroscope. For horizontal measurement in single implant group, index holes were made on the marginal ridges in mesial aspect of tooth #2, distal aspect of tooth #4 and mesiopalatal cusp tip of tooth #14, while a single hole was placed on the buccal side of #3 tooth socket at 4mm apical position to the gingival margin to allow for vertical measurement.

To standardize the measurements in horizontal dimension, closed-tray impression posts were connected to the analogs, in which the circular top parts of the screws were crossed and the central points were used for reference upon horizontal measurement against the points made on teeth. Additionally, an index point was milled on the flat side in one of the closed-tray impression posts to antagonize the points that were made apical to the gingival margin on the buccal aspect of implants to be used for consistent vertical measurement. In group two (multiple implants), the vertical measurement was done on the implant in site #5 only. A computer system consisting of a stereomicroscope with a connected USB CCD camera (Amscope, Irvine, California, USA), a computer and a compatible measurement software used to record the measurements of the horizontal (anteroposterior and cross arch) and vertical distances.

Putty indexes were prepared and used to keep same angulation and distance from the camera. The horizontal and the vertical distances on the Typodont master models were measured 3 times for each dimension. The mean and standard deviation for each measurement of the Typodont master models were calculated and used as the control to compare amongst the 8 corresponding groups of poured stone casts.

To ensure reproducibility, each cast measurement repeated three times, and the corresponding mean values considered as the statistical units. The accuracy of casts fabricated 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 test group of each dimension.

Percentage of deviation = [(MCM - MTMM)/MTMM)] x 100

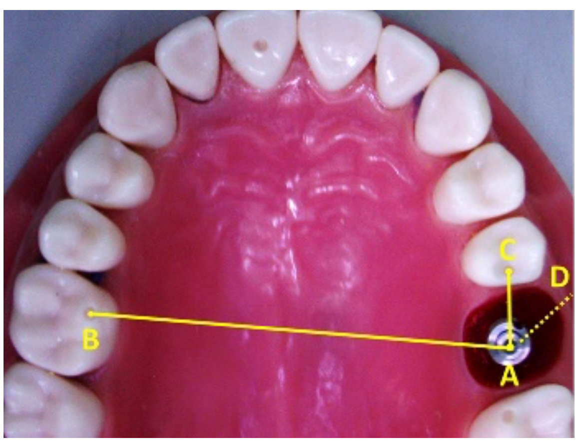

Figure 1: Maxillary Typodont hard model with single endosseous implant and reference points. {AB: Horizontal Cross-Arch (HCA); AC: Horizontal Anteroposterior (Ant-Post); AD: Vertical}. (Note: This is a mirror image generated by the stereomicroscope)

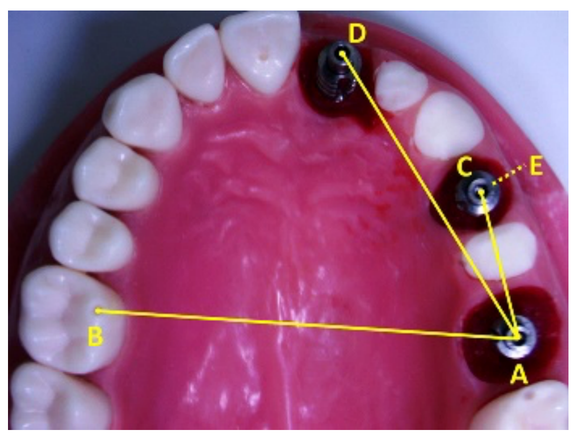

Figure 2: Maxillary Typodont hard model with multiple endosseous implants and reference points. {AB: Horizontal Cross-Arch (HCA); AC: Horizontal Inter-implant Straight (HIS); AD: Horizontal Inter-implant Curved (HIC); CE: Vertical}. (Note: This is a mirror image generated by the stereomicroscope)

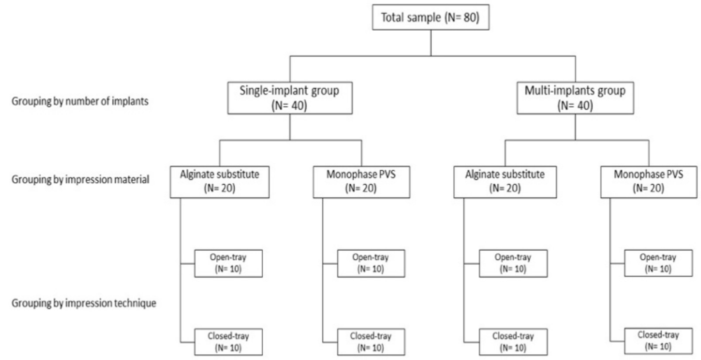

Figure 3: Sample distribution (AS: alginate substitute, MP: monophase PVS)

Statistical analysis

A descriptive statistic was done to calculate the mean, median, and standard deviation. Independent sample T-test and Mann-Whitney U Test were used to determine the differences between the test groups. Data were processed using a statistical software package SPSS for Windows, version 21 (SPSS Inc., Chicago, Illinois, USA). For all statistical analysis the level of significance was set at $p < 0.05$.

RESULTS

The means and standard deviations of the horizontal (cross arch and ant-post.) and vertical measurements of the master model and tested subgroups are shown in Table 1. It can be noted that the mean values of the tested subgroups are close to that of the master model, particularly AS and MP impressions with closed-tray technique in the single-implant group and AS and MP impressions with open-tray technique in the multi-implants group.

Table 1: Descriptive statistics (Mean±SD) of the tested subgroups in both single- and multi-implants groups

Material	Technique	Single implant			Multiple implants		
		Ant. Post.	Cross Arch	Vertical	Ant. Post.	Cross Arch	Vertical
Master model (*reference*)		8.22	44.11	18.77	35.53	42.64	17.32
Alginate Substitute		8.20±0.26	44.17±0.58	18.84±0.29	35.48±0.26	42.55±0.22	17.20±0.19
Monophase PVS		8.23±0.05	44.12±0.05	18.78±0.05	35.48±0.12	42.61±0.17	17.30±0.28
Alginate Substitute	Close Tray	8.20±0.19	44.08±0.25	18.72±0.16	35.40±0.35	42.51±0.31	17.06±0.13
	Open Tray	8.20±0.32	44.26±0.79	18.96±0.35	35.56±0.08	42.60±0.08	17.34±0.12
Monophase PVS	Close Tray	8.22±0.03	44.10±0.06	18.77±0.03	35.44±0.16	42.56±0.22	17.27±0.40
	Open Tray	8.24±0.06	44.13±0.04	18.79±0.07	35.52±0.03	42.65±0.06	17.32±0.03

The interaction effect of the independent variables (material and technique) is shown in Table 2. The overall effect of both variables was not significant in both single- and multi-implants groups. However, the effect of the technique was significant in both groups (P= 0.041 for the single-implant group and P= 0.022 for the multi-implants group).

Table 3 presents the differences between the different tested subgroups. In single-implant group, there were significant differences in the vertical measurements between AS open-tray and AS closed-tray (mean diff.= -0.24; $CI_{95\%}$= -0.50, 0.01; P= 0.008) and between AS open-tray and MP open-tray (mean diff.= 0.17; $CI_{95\%}$= -0.07, 0.41; P= 0.003). In multi-implants group, the differences were found in cross-arch and vertical dimensions between AS open-tray and AS closed-tray subgroups (P= 0.049 and P≤ 0.01, respectively). No other significant differences were found (P> 0.05).

Dispersion of the measurements around the fixed values of the master model is presented in Table 4. Generally, no significant differences were found between the measurements of the tested subgroups and the fixed values of the master model across all dimensions in both single- and multi-implants groups, except for the vertical dimension in the multi-implants group for AS closed-tray subgroup (P≤ 0.01). Figures 4 and 5 show the percentage of deviations of the tested subgroups in both single and multi-implants groups, respectively. It can be noted that the distortion which exceeded the allowed value of 0.5 per cent was found in AS open-tray subgroup for the vertical dimension in the single-implant group, and in AS closed-tray subgroup for the vertical dimension in the multi-implants group.

Table 2: 2-way ANOVA for the interaction effect of impression materials and techniques in both single- and multi-implants groups

	Anterior Posterior			**Cross Arch**			**Vertical**		
Source	**Type III Sum of Squares**	**F**	**P**	**Type III Sum of Squares**	**F**	**P**	**Type III Sum of Squares**	**F**	**P**
				Single implant					
Corrected Model	.010	0.09	0.963	.208	0.40	0.751	.330	2.85	0.051
	2697.15	74202.83	≤ 0.01	77946.83	453885.12	≤ 0.01	14151.89	366539.63	≤ 0.01
Impression	0.01	0.22	0.645	0.03	0.17	0.686	0.03	0.90	0.349
Technique	0.00	0.05	0.830	0.12	0.69	0.413	0.17	4.51	**0.041**
Impression * Technique	0.00	0.02	0.895	0.06	0.36	0.553	0.12	3.13	0.085
Error	1.31			6.18			1.39		
Total	2698.47			77953.22			14153.61		
Corrected Total	1.32			6.39			1.72		
				Multiple implants					
Corrected Model	0.159	1.351	0.273	0.107	0.920	0.441	0.519	3.581	0.023
	50351.80	1280112.35	≤ 0.01	72523.96	1866128.12	≤ 0.01	11899.40	246470.60	≤ 0.01
Impression	0.00	0.00	0.949	0.03	0.72	0.401	0.10	2.09	0.157
Technique	0.14	3.66	0.064	0.08	2.04	0.162	0.28	5.74	**0.022**
Impression * Technique	0.02	0.39	0.538	0.00	0.00	0.987	0.14	2.91	0.097
Error	1.42			1.40			1.74		
Total	50353.37			72525.47			11901.65		
Corrected Total	1.58			1.51			2.26		

Table 3: Pairwise comparison between the different subgroups in both single- and multi-implants groups

	Single implant		**Multiple implants**	
	Mean diff. (95% CI)	**P**	**Mean diff. (95% CI)**	**P**
AS Open- and Closed-tray techniques				
Anterior Posterior	-0.01 (-0.25, 0.24)	0.762	-0.16 (-0.41, 0.10)	0.130
Cross Arch	-0.19 (-0.76, 0.39)	0.571	-0.09 (-0.31, 0.13)	**0.049**
Vertical	-0.24 (-0.50, 0.01)	**0.008**	-0.29 (-0.40, -0.17)	**≤ 0.01**
MP Open- and Closed-tray techniques				
Anterior Posterior	-0.02 (-0.06, 0.02)	0.240	-0.08 (-0.20, 0.04)	0.172
Cross Arch	-0.03 (-0.08, 0.02)	0.271	-0.09 (-0.25, 0.07)	0.226
Vertical	-0.02 (-0.07, 0.03)	0.288	-0.05 (-0.34, 0.24)	0.762
MP and AS with Closed-tray technique				
Anterior Posterior	-0.02 (-0.16, 0.12)	0.940	-0.03 (-0.29, 0.22)	0.597
Cross Arch	-0.02 (-0.21, 0.16)	0.211	-0.05 (-0.31, 0.20)	0.325
Vertical	-0.05 (-0.17, 0.07)	0.705	-0.22 (-0.51, 0.07)	0.121
MP and AS with Open-tray technique				
Anterior Posterior	-0.04 (-0.27, 0.20)	0.473	0.04 (-0.02, 0.10)	0.082

Cross Arch	0.13 (-0.43, 0.69)	0.970	-0.05 (-0.11, 0.01)	0.140
Vertical	0.17 (-0.07, 0.41)	**0.003**	0.02 (-0.07, 0.11)	0.879

Table 4: One sample t-test for the dispersion of the measurements around the fixed values of the master model measurements

	Single implants			**Multiple implants**		
	Ant. Post. Test Value = 8.22			**Ant. Post. Test Value = 35.53**		
	t(df)	**Mean diff. (95% CI)**	**P**	**t(df)**	**Mean diff. (95%CI)**	**P**
AS Closed-tray technique	-0.41(9)	-0.03 (-0.16, 0.11)	0.692	-1.15(9)	-0.13 (-0.38, 0.12)	0.279
AS Open-tray technique	-0.20(9)	-0.02 (-0.25, 0.21)	0.849	1.26(9)	0.03 (-0.02, 0.09)	0.239
MP Closed-tray technique	-0.49(9)	-0.01 (-0.03, 0.02)	0.637	-1.80(9)	-0.09 (-0.21, 0.02)	0.105
MP Open-tray technique	0.92(9)	0.02 (-0.02, 0.06)	0.383	-1.10(9)	-0.01 (-0.04, 0.01)	0.301
	Cross arch Test Value = 44.11			**Cross arch Test Value = 42.64**		
AS Closed-tray technique	-0.41(9)	-0.03 (-0.21, 0.15)	0.689	-1.34(9)	-0.13 (-0.35, 0.09)	0.215
AS Open-tray technique	0.62(9)	0.15 (-0.41, 0.72)	0.551	-1.71(9)	-0.04 (-0.10, 0.01)	0.121
MP Closed-tray technique	-0.42(9)	-0.01 (-0.05, 0.04)	0.686	-1.08(9)	-0.08 (-0.24, 0.08)	0.307
MP Open-tray technique	1.59(9)	0.02 (-0.01, 0.05)	0.146	0.63(9)	0.01 (-0.03, 0.05)	0.543
	Vertical Test Value = 18.77			**Vertical Test Value = 17.32**		
AS Closed-tray technique	-1.01(9)	-0.05 (-0.17, 0.06)	0.338	-6.68(9)	-0.27 (-0.35, -0.18)	**≤ 0.01**
AS Open-tray technique	1.71(9)	0.19 (-0.06, 0.44)	0.121	0.51(9)	0.02 (-0.07, 0.11)	0.621
MP Closed-tray technique	-0.11(9)	0.00 (-0.02, 0.02)	0.915	-0.36(9)	-0.05 (-0.33, 0.24)	0.725
MP Open-tray technique	1.01(9)	0.02 (-0.03, 0.07)	0.341	0.21(9)	0.00 (-0.02, 0.02)	0.842

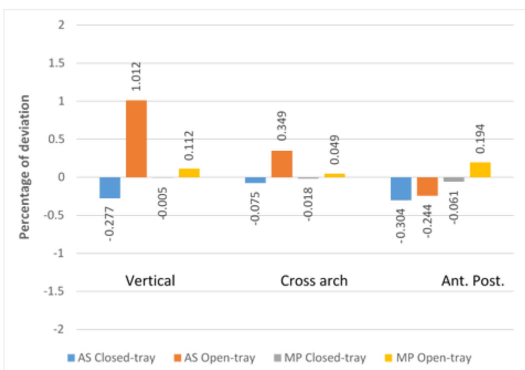

Figure 4: Percentage of deviation of the tested subgroups in single-implant group

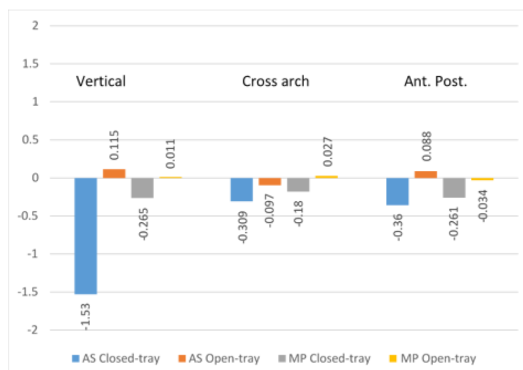

Figure 5: Percentage of deviation of the tested subgroups in multi-implants group

DISCUSSION

Similar studies have been done to test the included study parameters, however this study is the first to use typodont jaw models with acceptable implant positions and locations to represent realistic clinical scenarios. In addition, it is the first to test the accuracy of alginate substitute against one of the contemporary PVS materials to introduce its potential application in the field of implant dentistry.

The most important problem with dental implant prostheses misfit is that implants do not have periodontal ligament.[16] Thus, all applied forces to the implants are transmitted directly through the alveolar bone without damping on the bone-implant connection.[17,18]

The dental implant is considered the treatment of choice for both partially and completely edentulous ridges, and it provides good esthetic results that offer satisfactory prosthetic restorations. The dental prostheses are secured to the osseointegrated dental implants and deliver better stability, retention, and esthetics, thus increasing the satisfaction of the patients.[16,19,20]

The impression technique is considered one of the important factors causing marginal misfit and increase the strain on the dental implant prostheses.[1] The impression also has the important purpose of registering the morphology of soft tissues.[21,22] Dental implant prosthesis misfit may result from an inaccurate impression, which may result in biological and/or mechanical complications.[1] Mechanical complications as a result of prosthesis misfit are reported such as implant fracture, screw fracture, screw loosening, and occlusal inaccuracy, have been reported.[23,24] The misfit that happens from marginal discrepancy may cause biological complications such as adverse reactions on soft or hard tissue due to increased biofilm growth.[25]

The results of the present study reject acceptance of the null hypothesis. There were no significant differences between monophase PVS and alginate substitute impression materials in most of the measured dimensions across both techniques. In the present study, monophase PVS and alginate substitute impression materials were used. The contemporary silicone-based impression materials are the materials of choice in implant prosthodontics because of its superior properties including high dimensional stability, high elastic recovery, excellent details reproduction and good wettability and tear strength.[26] Despite of their high physical and mechanical properties, Hulme et al reported that clinical uses of such materials are associated with higher cost on clinicians, patients or third-party funders.[27] Alginate substitute is a low-cost medium body PVS that recommended to be a superior alternative to conventional irreversible hydrocolloid. These impression materials have been reported to offer improved detail reproduction, tear strength, and dimensional stability.[28]

In the present study, it was found that there was no statistical significance difference between the open and closed tray impression techniques using the monophase PVS material. This is in agreement with the findings of Osman et al and Wenz et al.[29,30] In contrast, Daoudi et al and AlQuran et al found that the open tray impression technique was more accurate and significantly superior to closed tray impression technique.[31,32]

In the present study, it has been found that, in single implant group, the absolute changes (in μm) from typodont model for the closed tray technique using monophase PVS impression material were small compared to those of the open tray technique using monophase PVS impression material. This result is in agreement with Balouch et al who found that the closed impression technique demonstrated less dimensional changes.[33]

However, in the second group of three implants with an intermediate implant off inter-abutment axis, the absolute changes (in μm) from typodont model for the monophase PVS open tray technique were small compared to those of the monophase PVS closed tray technique. This result can be explained by the curve distribution of the three implants that would result in distortion of impression when closed tray technique was used.

The present study found in both groups, the percentages of deviations and the absolute changes (in μm) from typodont model for PVS impression material were less compared to those of alginate substitute impression material however, the differences were not statistically significant. This finding supported the dimensional stability of alginate substitute impression material that was reported by Baxter et al.[28] Although, the PVS still the material of choice for multiunit implant restoration according the recommendation of Schmidt et al (2018), who reported that the impression material had the greatest effect on the impression accuracy and recommended the polyvinyl siloxane impression materials for multiunit restoration supported by non-parallel dental implants.[34] In contrast to previous findings, researchers found that, the PVS was not superior to other irreversible hydrocolloid materials if splinted impression coping technique was used for impression of multiunit implant restoration.[15,35] This, in vitro study, had some limitations. The position of implants was parallel which is a situation difficult to achieve in clinical scenarios because of anatomic structures limitations. The presence of intraoral fluids like saliva and blood will affect the accuracy of impression materials. Therefore, further in vivo studies are required to validate the results of this study.

CONCLUSION

Within limitation of this study, the alginate substitute impression material showed comparable accuracy to the monophase PVS impression material for single and three implants restorations. Almost, the open and closed tray impression techniques for alginate substitute impression material and monophase PVS materials showed the same level of accuracy for single and three implants restorations. The closed tray technique was more accurate than the open tray technique using alginate substitute impression material for single implant restoration. The open tray technique was more accurate than the closed tray technique when using alginate substitute impression material for three implant restorations.

Conflict of Interest

The author declares that there are no conflicts of interest relevant to this article.

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