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Influence of subgingival depth of implant on dimensional accuracy of open tray impressions made using single and 2 step technique with different impression materials

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Abstract
Objective: The purpose of the study is to evaluate and compare the effect of subgingival depth of the implant on the accuracy of the open tray implant impressions made using single step and 2 step technique with different impression materials.
Material and Method: The study was performed on a maxillary edentulous heat cure acrylic resin master model with 4 implant analogs embedded parallelly in canine and 1st molar region, bilaterally, at different subgingival depths of 2 mm, 3 mm, 4 mm and 5mm. A 30mm cylindrical rod was inserted in the center of palatal region of the master model to serve as a reference point from which the linear dimension of each impression coping was measured. Elastomers used to make open tray impression of the master model were medium body polyether and putty-light body addition silicone. Accordingly, the grouping was done. Group A- Single step impression technique using Medium Body Polyether impression material. Group B- Single step impression technique using Putty and Light Body Addition Silicone impression material. Group C-Two step impression technique using Putty and Light Body Addition Silicone impression material. Impressions were poured with Type IV Gypsum product (Die stone). The linear dimensional change was recorded by measuring distance of each impression coping from the central reference rod with Coordinate Measuring Machine (CMM). The data so obtained was compared and analyzed statistically.
Results: The results revealed that Group C produced more accurate implant impressions for deeply placed implants. Besides, Group A and Group B have produced comparable results.
Conclusion: It can be concluded that two step addition silicone impression technique may be used for producing accurate impressions of implants placed at deeper subgingival depth. Meanwhile, Polyether impressions and Single step addition silicone impression have shown comparable dimensional accuracy at all depths.

Keywords: Open tray implant impressions; polyether; addition silicone; single step impression technique; two step impression technique; impression copings; implant analogs; custom tray; dimensional accuracy

Introduction
Oral rehabilitation with dental implants has brought a revolutionary change in treatment of patients with partial or complete edentulism requiring functional and esthetic replacement. The longevity of an implant retained prosthesis is greatly dependent on making an accurate implant impression which plays a pivotal role in achieving a passively fitting prosthesis. Inability to produce a passive fit may be detrimental to the implant prosthesis due to generation of non-axial forces on the implant. According to Binon (1996) [1], poor fit between the implant and the prosthesis can lead to joint instability within the system. The clinically acceptable range for a prosthesis misfit is 30-150um (Aly Abdelrehim 2022) [13]. A number of variables influence the precision of dental impressions including the impression material, impression technique such as open and close tray technique, implant angulation, impression coping dimensions, design and surface treatment and the splinting material. In addition to

these factors, subgingival depth of the implant is an element that may influence the precision of dental implant impressions. Implants are frequently positioned deeper beneath the gum line due to limited bone availability or esthetic demands. As a result, a larger portion of the impression coping lies below the gingival margin, leaving less of it exposed above the gum line. This reduction in the visible part of the coping can compromise its engagement within the impression material, potentially decreasing its stability and negatively impacting the overall accuracy of the impression. Longer impression copings can be made use of to increase the stability of coping in sub-gingival implants, but this may hike the cost of the treatment. Also, an extension of impression coping was suggested by Lee (2008) [4]. In order to get a dimensionally precise implant impression, the type of impression technique used also is very important. Two most commonly used techniques for implant impression are open tray and closed tray impression technique. Besides literature recommends use of Polyether as well as Addition Silicone elastomers for making accurate implant impressions. According to Lee (2008) [3], deeper implants showed noticeably less accurate horizontal impressions for medium body polyether impressions. In a study by Vyonne J Hoods Moonsammy (2014) [7], PVS monophase material was found to be highly accurate. Not much has been investigated on the impact that subgingival depth of implant has on impression accuracy. Hence, in order to achieve results that are both clinically relevant and applicable, future research should employ more sophisticated study designs that better replicate real-world clinical conditions. To mitigate this ambiguity, an *in vitro* study was performed to evaluate the impact of implant subgingival depth on the dimensional accuracy of the open tray impression made using various impression materials and techniques.

Materials and Methods

A maxillary edentulous heat cure acrylic resin master model was fabricated using a silicone maxillary mold. 4 parallel implant analogs were embedded in canine and 1st molar regions at different subgingival depths of 2mm,3mm,4mm and 5mm.To measure the linear dimensional changes in the casts, a reference cylindrical rod was inserted in the center of the cast (Figure:1). Open tray impression copings were screwed to the implant analogs. Open tray impressions were made in a self-cure acrylic resin custom tray using medium body polyether and putty and light body addition silicone. The impressions posts were unscrewed and impression was separated from the master model. The implant analogs were attached to the copings and the cast was poured with type 4 gypsum product [die stone].

Steps in fabrication of master model

A silicone mold of ideal edentulous maxillary cast was filled with molten wax and wax model was removed after set. Holes were made into the wax model at canine and 1st molar region at depth of 2mm, 3mm, 4mm and 5mm and measured using a William's probe. A 30mm long cylindrical rod was inserted in the center of the wax model at a depth of 10mm, to serve as a reference for the linear measurements. Implant analogs were inserted into these holes and square open tray impression copings were screwed to the analogs. Parallelism was checked using dental surveyor. Flasking, dewaxing and packing with heat cure acrylic resin in dough stage was done. Acrylization was done with short curing cycle. The heat cure acrylic resin master model obtained with embedded implant analogs and impression copings along with the central reference rod was then finished and polished.

Fig 1: Heat cure acrylic resin master model

Fig 2: Group A

Fig 3: unscrewing impression posts before removing impression

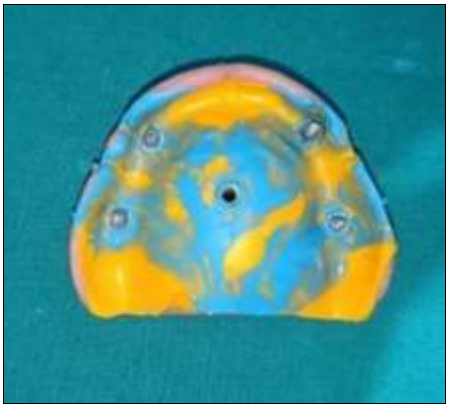

Fig 4: Group B

Fig 5: 1st Step of Group C

Fig 6: 2nd Step of Group C

Fig 7: Type IV Die Stone Cast

Fig 8: CMM machine to measure linear dimensions.

Steps in fabrication of custom tray

For fabrication of a custom tray, a 2 mm thick spacer wax was adapted over the master model with impression posts attached. Tissue stops, measuring 2 x 4 mm in dimensions, were made anterior to each implant analog. Self-cure acrylic resin was used to fabricate the custom tray on the master model. Perforations were made in the tray using interdental bur before making the impression.

Steps in impression making

Total 30 impressions were made. Total 30 impressions were made.10 impressions were made with Medium Body Polyether,10 each with putty and light body addition silicone elastomeric impression material using single-step and 2-step technique.

1.Polyether medium body impression

After removing the spacer wax, Polyether tray adhesive was painted on the custom tray and air-dried for 15 minutes. Impregum Penta Soft (medium body) impression material was mixed and dispensed around the impression copings & simultaneously loaded in custom tray. (Figure-2). The impression was allowed to set for 3 minutes. The impression copings were unscrewed and impression was taken off from the master model. (Figure-3).

2. Single step addition silicone putty- light body impression

Caulk tray adhesive was applied over the custom tray and allowed to dry for 15 minutes. Zhermack Elite light body was dispensed around the impression copings and PVS putty was hand mixed as per manufacturer's instructions and placed in the custom tray. Impression was allowed to set for 5 minutes and 30 seconds. (Figure-4).

3. Two step addition silicone putty- light body impression

a) In the first step, PVS putty was hand mixed as recommended by the manufacturer and loaded in the tray. A cellophane sheet was spread over the loaded putty and the custom tray was placed onto the master model. After setting of PVS putty, the impression was separated from the master model without unscrewing the impression copings. (Figure-5).
b) For the second step, the cellophane sheet was removed, and the light body was dispensed around the impression copings and on the putty in the custom tray. The custom tray was now again placed back over the master model. The impression of the master model was allowed to set for 4 minutes. (Figure-6).

Steps in pouring experimental casts

A 30 mm cylindrical rod was inserted into the central hole at depth of 10 mm. The implant analogs were attached to the impression posts taking care not to rotate the impression copings while tightening the analogs. The impression was poured using Type 4 gypsum (Die stone by Magic) (Figure-7).

Steps in coordinate measuring machine (cmm) measurements

Coordinate Measuring Machine (CMM) was used to record the distance of impression copings from the central reference rod. X, Y and Z coordinates of the center of the impression coping screws attached to the implant analogs were measured with central rod as a reference point. (Figure-8).

Results

Table 1: Mean values of distance of each impression coping from the center in each group

	D1	D2	D3	D4
MASTER MODEL	28.36589	26.6015	25.798	27.5579
POLYETHER	27.1772	26.2662	26.8359	29.1402
ADDITION SILICONE 1	26.3424	25.4812	26.5262	29.2139
ADDITION SILICONE 2	28.5321	26.0523	26.4302	27.9637

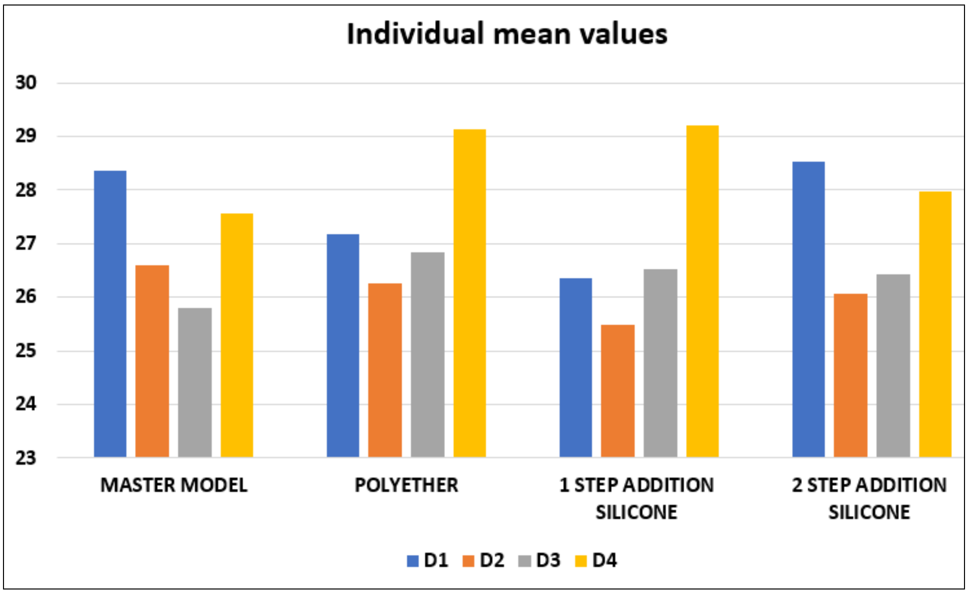

Table 2: ANOVA Test of Group A, Group B and Group C

	Sum of Square	df	Mean Square	F	P value	Significance
Group A						
Between Groups	46.738	3	15.579	1.542	0.22	NS
Within Groups	363.8	36	10.106			
Total	410.54	39				
Group B						
Between Groups	78.174	3	26.058	3.867	**0.017**	**S**
Within Groups	242.58	36	6.738			
Total	320.75	39				
Group C						
Between Groups	42.594	3	14.198	2.766	0.056	NS
Within Groups	184.81	36	5.134			
Total	227.4	39				

Table 3: ANOVA TESTS For comparisons of linear distance D1, D2, D3 And D4 of all the groups.

	Sum of Square	df	Mean Square	F	P value	Significance
Comparison of linear distance D1 using ANOVA Test						
Between Groups	28.763	3	9.588	1.027	0.394	NS
Within Groups	289.28	31	9.332			
Total	318.04	34				
Comparison of linear distance D2 using ANOVA Test						
Between Groups	5.207	3	1.736	0.238	0.869	NS
Within Groups	225.94	31	7.288			
Total	231.15	34				
Comparison of linear distance D3 using ANOVA Test						
Between Groups	3.637	3	1.212	0.226	0.878	NS
Within Groups	166.24	31	5.363			
Total	169.88	34				
Comparison of linear distance D4 using ANOVA Test						
Between Groups	43.444	3	14.481	3.762	0.021	S
Within Groups	119.33	31	3.849			
Total	162.78	34				

Table 4: Post Hoc Tukey's Test of Group A, B and C.

	GROUP A				GROUP B				GROUP C			
	Mean	S.D	P value	Significance	Mean	S.D	P value	Significance	Mean	S.D	P value	Significance
D1	27.18	4.18	0.918	NS	26.34	2.85	0.879	NS	28.53	2.44	0.086	NS
D2	26.27	3.43			25.48	2.88			26.05	2.2		
D1	27.18	4.18	0.995	NS	26.34	2.85	0.999	NS	28.53	2.44	0.181	NS
D3	26.84	2.44			26.53	2.35			26.43	2.62		
D1	27.18	4.18	0.519	NS	26.34	2.85	0.081	NS	28.53	2.44	0.943	NS
D4	29.14	2.28			29.21	2.24			27.96	1.69		
D2	26.27	3.43	0.978	NS	25.48	2.88	0.805	NS	26.05	2.2	0.982	NS
D3	26.84	2.44			26.53	2.35			26.43	2.62		
D2	26.27	3.43	0.199	NS	25.48	2.88	0.014	**S**	26.05	2.2	0.252	NS
D4	29.14	2.28			29.21	2.24			27.96	1.69		
D3	26.84	2.44	0.38	NS	26.53	2.35	0.113	NS	26.43	2.62	0.44	NS
D4	29.14	2.28			29.21	2.24			27.96	1.69		

Table 5: Post hoc Analysis of implant analogs placed at different subgingival depths.

	Mean	S. D	P value	Significance
	D1			
CONTROL	28.36	1.12	0.894	NS
GROUP A	27.18	4.18		
CONTROL	28.36	1.12	0.629	NS
GROUP B	26.34	2.85		
CONTROL	28.36	1.12	0.998	NS
GROUP C	28.53	2.44		
GROUP A	27.18	4.18	0.928	NS
GROUP B	26.34	2.85		
GROUP A	27.18	4.18	0.755	NS
GROUP C	28.53	2.44		
GROUP B	26.34	2.85	0.392	NS
GROUP C	28.53	2.44		
	D2			
CONTROL	26.6	0.68	0.996	NS
GROUP A	26.27	3.43		
CONTROL	26.6	0.68	0.873	NS
GROUP B	25.48	2.88		
CONTROL	26.6	0.68	0.982	NS
GROUP C	26.05	2.2		
GROUP A	26.27	3.43	0.915	NS
GROUP B	25.48	2.88		
GROUP A	26.27	3.43	0.998	NS
GROUP C	26.05	2.2		
GROUP B	25.48	2.88	0.964	NS
GROUP C	26.05	2.2		
	D3			
CONTROL	25.8	0.56	0.845	NS
GROUP A	26.84	2.44		
CONTROL	25.8	0.56	0.939	NS
GROUP B	26.53	2.35		
CONTROL	25.8	0.56	0.959	NS
GROUP C	26.43	2.62		
GROUP A	26.84	2.44	0.991	NS
GROUP B	26.53	2.35		
GROUP A	26.84	2.44	0.979	NS
GROUP C	26.43	2.62		
GROUP B	26.53	2.35	0.998	NS
GROUP C	26.43	2.62		
	D4			
CONTROL	27.55	0.61	0.029	S
GROUP A	29.14	2.28		
CONTROL	27.55	0.61	0.025	S
GROUP B	29.21	2.24		
CONTROL	27.55	0.61	0.269	NS
GROUP C	27.96	1.69		
GROUP A	29.14	2.28	0.998	NS
GROUP B	29.21	2.24		
GROUP A	29.14	2.28	0.545	NS
GROUP C	27.96	1.69		
GROUP B	29.21	2.24	0.494	NS
GROUP C	27.96	1.69		

The ANOVA test result (Table for each experimental group and control group demonstrated that

- Group B revealed a statistically significantly higher difference in linear dimensional change as compared to the control group.as shown by the p value of 0.017(p< 0.05) (Table-3). (Table-2).
- A statistically significantly higher difference in the linear dimensional change was found between the experimental groups and control groups for implant analog placed at 5mm subgingival depth as depicted by p-value of 0.021(p<0.05). (Table-3).

The Post hoc tukey's test conducted between control group and experimental group for all the implant analogs placed at different subgingival depth indicated that:

- In Group B, a statistically significantly higher difference in linear dimensional change between the implant analogs placed at 3 mm(D2) and 5 mm(D4) subgingival depth was observed as shown by the p-value of 0.014(p<0.05). (Table-4).
- For the implant analog placed at 5mm subgingival depth, a statistically significantly greater difference between control group and Group A was evident as shown by P-value of 0.029(p<0.05. (Table-5).
- For the implant analog placed at 5mm subgingival depth, a statistically significantly higher difference between Control group and Group B was observed as shown by p value of 0.025(p<0.05). (Table-5).

Discussion

Dental implants have become the ultimate treatment option for replacement of single or multiple missing teeth as they enhance self-assurance by providing oral comfort during mastication, improved aesthetics and notable degree of contentment. Achieving the long-term success of dental implant prosthesis relies on producing a prosthesis with a passive fit, which depends on a dimensionally accurate implant impression. The accuracy and fit of multiunit implant prostheses can be influenced by dimensional alterations during clinical and laboratory procedures, as well as by the movement of impression copings or implant replicas during the impression-taking process. (Ibrahim 2020) [11]. Additionally, it depends on a number of variables, such as the depth and angulation of the implant, the machining forbearance of the prosthetic components, the physical and mechanical characteristics of the impression material, the impression technique used, the splinting method and material used, the choice of the impression tray, the accuracy of the gypsum product used to pour the cast (Shabab A Khan 2021) [12]. The present *in vitro* study was conducted to determine the effect of subgingival depth of an implant on the accuracy of implant impressions made using different impression materials and techniques. The impression materials used were Polyether and Addition Silicone elastomers. The impression technique used were single-step and 2-step open tray implant impression technique

The ANOVA test analysis of the 3 groups in the present study, recorded a significant linear dimensional change was observed in Group B whereas in Group A and Group C, the changes were non-significant when compared to the control group. Group B revealed a statistically significantly higher difference in linear dimensional change as compared to the control group.as shown by the p value of 0.017(p< 0.05). Post Hoc Tukey's test results for the experimental groups have depicted a significantly more difference in the linear dimensional change in Group B when implant analogs placed at 2mm and 4mm were compared as indicated by the p value of 0.014(p<0.05). For implant analogs placed at a subgingival depth of 5 mm, a statistically significantly greater difference in linear dimensions was found between the experimental groups and the control group as shown by the p-value of 0.021 (p<0.05). The post hoc Tukey's test was performed between each experimental group and the control group, for implant analogs placed at 5 mm subgingival depth(D4). It indicated a statistically significant difference between Group A and Group B and the Control Group. In the present study, the superior results in Group C for implant analogs placed 2mm, 4mm and 5 mm can be can be explained by higher flexibility and elastic recovery as observed by Zerrin (2013) [5] in their *in vitro* study. They stated that the material's flexibility, excellent elastic recovery, superior tensile strength and good flow becomes increasingly important, as greater stress is exerted on the impression material during removal. In such cases, Polyvinyl Siloxane (PVS)offers a clear advantage. The results were in agreement with results of a study done by Sakshi Garg (2019) [10], who found that the two-step putty and light body Addition Silicone impression techniques provided the most precise results as compared to monophase Addition Silicone. Pravin Kumar G Patil (2015) [8] demonstrated a technique of making two step implant impression technique, that allows for greater accuracy because the pressure applied to the implant analogs is minimal and equally distributed. Least dimensional change in Group A for implant analog placed at 3 mm subgingival depth may be accounted for the stiffness, hydrophilicity and greater dimensional accuracy of polyether elastomer. Wee (2000) [2] compared the torque resistance of PVS and polyether elastomers and found Polyether to have the highest values, which could be advantageous for making an accurate open tray impression. Group A has shown lesser dimensional accuracy than Group C for implant analogs placed at 4 mm subgingival depth. The result matched with the results of an *in vitro* study conducted by Lee (2008) [3] who observed that the direct impression made using medium body polyether exhibited lower accuracy than PVS impression of implants placed at deeper subgingival depth. They recommended use of 4 mm extension to the impression coping in order to eliminate the inaccuracy. Many studies have shown that PVS impressions exhibited higher accuracy than the polyether impressions. Vojdani (2014) [6] evaluated the accuracy of three elastomers—PE, PVS, and vinyl siloxane ether—using the open tray technique. They came to the conclusion that PVS was the preferred option, followed by PE and vinyl siloxane ether as PVS has higher tensile strength, more elastic recovery and better flowability. These results support the higher accuracy achieved for Group C in this study. Ravi Shankar (2016) [9] inferred that VSE demonstrated the smallest mean deviation, succeeded by polyether and PVS, in both open and closed tray techniques, irrespective of the splinting material employed. Integrating the qualities of PE and PVS into a newer However, there were few limitations in the study.

The findings of this study were based on a sample of four implants and may not be applicable to impressions involving a greater or fewer number of implants. Moreover, all the implant analogs were inserted parallel in the master model in order to eliminate effect of implant angulation, contrary to the clinical situations where multiple implants are rarely parallel. method of tray removal did not accurately replicate conditions within the oral cavity. and was conducted at right angle to the occlusal plane. It can be concluded from the study that, for implant analogs placed at deeper subgingival depth, Group C has produced statistically significantly more dimensionally accurate results than Group A followed by Group B. In intragroup comparison, statistically significant results in linear dimensional change were recorded in Group B for implant analogs placed at 3mm and 5mm subgingival depth.

Taking the study's limitations into account, it may be concluded that for reproducing the intraoral position of implants into the definitive cast, various impression materials and techniques are employed**.** For making implant impressions of implant analogs placed at deeper subgingival depths, two step addition silicone impression may result in more dimensional accuracy as compared to one step addition silicone impression and polyether impression. This can be explained by the fact that putty impression made in first step acts as a custom tray and it confines the light body material into the deeper subgingival levels of the implant analogs during the second step of impression making. Meanwhile, Polyether impressions and One step addition silicone impression have shown comparable dimensional accuracy at all depths. Given the findings, it can be summarized that Addition Silicone and Polyether are viable alternatives for making accurate implant impression making and the Two-Step Addition Silicone technique appears to offer superior accuracy for implant analogs placed at greater subgingival depths. However, further studies are necessary to validate these results.

Summary and Conclusion

Dental implant therapy is widely utilized to rehabilitate both partially and completely edentulous patients, helping restore normal function, comfort, esthetics, and overall health. It is crucial to accurately replicate the implant's position within the mouth onto the final cast., enabling the precise fabrication of a passively fitting implant-supported prosthesis. This study aimed to determine the influence of subgingival depth of implant on the dimensional accuracy of open tray impressions made using single and 2 step impression technique with different elastomers.

- Group B revealed a statistically significantly higher difference in linear dimensional change as compared to the control group.as shown by the p value of 0.017($p<$ 0.05). (Table-2).
- A statistically significantly higher difference in the linear dimensional change was found between the experimental groups and control groups for implant analog placed at 5mm subgingival depth(D4) as depicted by p-value of 0.021($p<0.05$). (Table-3).
- For the implant analog placed at 5mm subgingival depth (D4), a statistically significantly greater difference between control group and Group A was evident as shown by P-value of 0.029($p<0.05$. (Table-5).
- For the implant analog placed at 5mm subgingival depth (D4), a statistically significantly higher difference between Control group and Group B was observed as shown by p value of 0.025($p<0.05$). (Table-5).

Following conclusions were drawn from the analysis of the results

1. With increasing subgingival depth, more linear discrepancy was observed between Control group and all the Experimental Groups.
2. Relatively higher distortion was evident in Group B.
3. Group C showed less linear distortion with increasing subgingival depth in comparison to the Control Group.

Currently, there is a lack of strong evidence supporting any certain impression method or material that can be used to obtain a precise implant impression. The two-step impression approach can yield satisfactory outcomes in implant impressions. It is clinician's decision to use a combination of a specific impression material and impression technique for achieving a passively fitting prosthesis which is essential for the long-term success of implant supported prosthesis.

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