Original Article

Comparison of implant cast accuracy of multiple implant impression technique with different splinting materials: An *in vitro* study

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Abstract

Introduction: An accurate and passive fit of implant framework prosthesis, as well as the successful surgical operation is suggested as one of the critical requirements for long-term implant success.

Objective: The purpose of this *in vitro* study was to evaluate the accuracy of the master cast using open tray impression technique with conventional and novel splinting materials.

Methodology: A mandibular reference model with four ADIN implants was done. Ten custom trays were fabricated using the light curable resin sheets. Medium body polyether impression material was used. These trays were randomly divided between the two groups, with five trays in each group. Impression techniques were divided into two groups namely: Group A: Direct impression technique with open tray impression copings splinted with autopolymerizing acrylic resin (GC pattern resin). Group B: Direct impression technique with open tray impression copings splinted with Pro-temp TM 4 (bis-GMA) syringable temporization material. Thus, final impressions were made. Total of 10 master casts were fabricated. Evaluation of casts using Dynascope-Vision Engineering, TESA microhite two- dimension and coordinate measuring machine were used.

Results: Statistical comparisons were made using ANOVA test and *post-hoc* test. Same amount of deviation values obtained with resin splinted and bis-GMA splinted impression copings.

Conclusion: The master cast obtained by both the splinting material exhibits no difference from the reference model. So bis-GMA can be used, which is easy to handle, less time consuming, less technique sensitive, rigid, and readily available material in clinics.

Key Words: Accuracy, direct implant impression, master cast, splinting materials

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INTRODUCTION

Osseointegrated implants have provided alternative treatments option to conventional prosthesis for patients who were partially and completely edentulous and achieved predictable

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and favorable long-term results.[1,2] An accurate and passive fit of an implant framework prosthesis, as well as the successful surgical operation is suggested as one of the critical requirements for long-term implant success.[3-8] Presence of uneven distribution of occlusal loads and torquing stresses on the various portion of implant elements causes problems related to poor fit of frameworks connected to implant and may also lead to marginal bone loss and failure of implants, as well as in relation to mechanical problems as loosening of screws and fatigue fractures of implant components.[4-10] It may not be probably possible to connect a multi-unit implant prosthesis with a completely passive fit in clinical situation because there are many potential inaccuracies with current materials and techniques, which include dimensional changes in impression materials, expansion of gypsum die product, dimensional changes in wax and acrylic pattern, dimensional changes in investment materials and volumetric shrinkage of metal casting on solidification and the clinicians skill.[11]

Among these variables, the precise transfer of the spatial relationships of implants from the mouth to the master cast with an impression is the first and crucial step to ensure passive fit of implant framework. Therefore, clinicians should strive for improving and precise transfer of the impression copings.[12-14] Various implant techniques have been suggested in the literature to achieve an accurate master cast.

In regard to splint the impression copings, there are many controversies exist since Branemark *et al*. emphasized the importance of splinting impression copings together before registration of multiple implant impression.[15]

The common practice of joining the direct transfer copings with acrylic resin is an attempt to stabilize the copings against rotation during fixture or abutment analog fastening, control the relationship between implants in a rigid fashion However, varies literature studies showed no significant differences between the values obtained with acrylic-splinted versus unsplinted groups in impression technique.[12,16-18]

Studies involved multiple variables of techniques and materials, the consistent findings was one of distortion resulting from the transfer manipulations.[19] The same objective could be partially accomplished with a rigid impression material or an elastic material with a low flexibility, both of which do not introduce the polymerization shrinkage variables inherent in the use of acrylic resin. Vigolo *et al*.[20] suggested that the impression technique involved square impression copings joined together with autopolymerizing acrylic resin or square impression copings, previously airborne particle-abraded and adhesivecoated could improve accuracy of the master cast than nonmodified squared transfer coping without splinting. Cabral and Guedes[21] compared four impression techniques and direct impression technique with square impression coping with acrylic resin splints sectioned 17 min after setting and welded with the same resin before impression making showed better results than other techniques studied.

Among the direct impression techniques, both splinting and nonsplinting have been advocated for accurate impressions. Although splinting with resin, impression plaster or bite registration material has been recommended for maintaining a more accurate inter implant relationship, the accuracy of these techniques in yielding accurate casts is controversial.[20,22,23] In order to have rigid and dimensional stable material a newer material bis-GMA has been used to splint the impression copings. The purpose of this *in vitro* study was to evaluate the effect of dimensional stability of conventionally used and newer splinting materials on the accuracy of master casts.

MATERIALS AND METHODS

A reference wax model with four implants (ADIN Dental Implant System Ltd, Afula Israel.) in the mandibular anterior region in overdenture position A, B, D, and E was positioned using surveyor for the proper orientation [Figure 1]. The reference model mimics a mandibular implant-supported overdenture situation. Three stoppers, one in the anterior and two in the posterior region were made in the land area of the mandibular reference model, this ensures the proper orientation of the impression trays. Fabricated in clear heat cure acrylic resin (Triplex, Ivoclor, Vivadent) [Figure 2]. A preliminary cast was fabricated using indirect impression technique. In-order to obtain uniform spacer, 3 mm even spacer was adapted onto the primary cast and the impression made and spaced primary cast was obtained [Figure 3]. Ten custom trays (five per group) with windows in the anterior region were made using light cure acrylic resin sheets Sheet (Plaque Photo, W + P Dental, Hamburg, Germany)

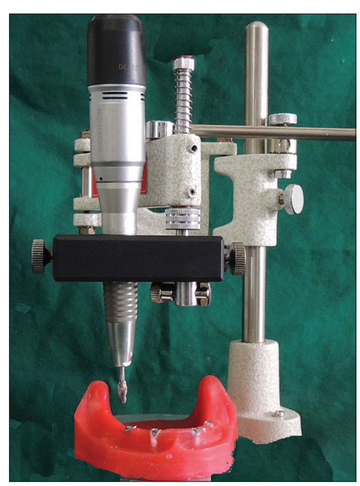


Figure 1: Reference wax model with four implants

of 2 mm in thickness [Figure 4]. All the custom trays are uniformly spaced. To ensure dimensional stability of custom tray, the trays are left undisturbed for 24 h prior to impression making. The tray samples were divided randomly into two groups based on impression technique.

- In Group A, the open tray impression copings were screwed to the implant body at 15 Ncm torque. The open tray copings where splinted with dental floss (Oral B waxed dental floss, India). Autopolymerizing resin (GC pattern resin, Osaka, Japan) was mixed in the ratio of 2 g–1 ml. When the resin reached the dough stage, it was packed around the impression posts and the dental floss thus they were splinted together. The splint was allowed to polymerize for 4 min. The splint was then sectioned in-between the impression posts using a thin separating disc to relieve the stresses caused due to polymerization shrinkage. The cut sections were joined using the same resin by applying it using brush bead method [Figure 5]. This was again allowed to polymerize for 4 min. The impression copings, custom tray, and the splint were coated with polyether adhesive and allowed to dry for 15 min
- In Group B the procedure of impression making was similar to Group A except that instead of pattern resin, bis-GMA (Pro-temp 4 3M ESPE, India) was used. The shrinkage of the material is lesser than autopolymerizing resin, so the splints were not sectioned in-between the impression posts. The bis—GMA (Pro-temp 4 3M ESPE, India) was just syringed using an automix gun (3M ESPE, India) into floss matrix formed between the impression post [Figure 6]. It is allowed to set for about 7 min as per the manufacturer's instructions. Once the splinting was rigid then the impression copings, custom tray and the splint were all coated with polyether adhesive [Figure 7].

The medium body polyether was machine mixed (3M ESPE pentamix 2 Germany) and dispensed into a penta elastomer syringe (3M ESPE, Germany). It was syringed around the impression copings to avoid impression defects around the copings and loaded in the custom tray. The tray was then carried onto the reference model immediately and the impression

Figure 2: Reference model in heat cure clear acrylic resin

Figure 3: Spaced primary cast

Figure 4: Resin sheet adapted to the spaced primary cast

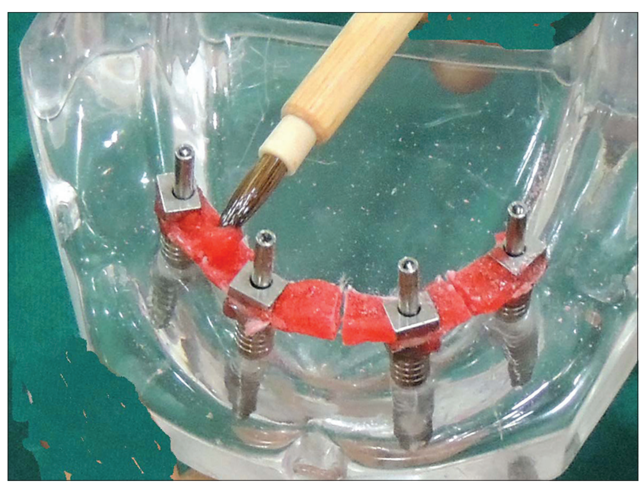


Figure 5: Reunion of sections by brush bead method

made. It was made sure that the tray seated completely in the three stops that were made in the reference model to ensure complete seating and proper positioning of the custom tray. The impression was allowed to set for 6 min as per the manufacturer's recommendation. The screws of the impression posts were unscrewed and the impression removed from the reference model [Figure 8]. A total of five impressions were made in each group in a similar manner. The implant replica was fastened on to the impression copings and impressions were poured using Type IV dental stone (Ultrarock, Kalabhai). A total of 10 master cast were obtained [Figure 9] and only one model was obtained from each impression.

Measurement protocol

The reliability of measuring system is vital to evaluate the accuracy of the impression. Because distortion of an impression can occur in X, Y, and Z axis, so its of paramount importance to analyze the distortion in three dimensions.

Dynoscope-Vision engineering (TESPA Calibration centre) was used to measure the X and Y axis. The magnified image of each implant in reference model and implant replica in the master casts were visualized in the computer and the external margin of each implant and implant replica was taken as reference point. The co-ordinates of the center of replica one was measured and zeroed and kept as (X_0, Y_0). Keeping this as the reference position the centers of the other three replicas were determined and the linear distance between the centers of implant/replica were all measured in the X and Y planes. Thus, the linear distance between the centers of replica/implant are 1 and 2 (*D1 x*/y), 1 and 3 (*D2 x*/y) and 1, and 4 (*D3 x*/y) were all measured digitally [Figures 10 and 11].

TESA microhite two- dimension (TESPA Calibration centre) was used to find the planes formed by the platform of implant and replica. The probe was used to measure the plane formed by the platform of Implant/replica 1 and it was zeroed. The distance between the plane formed by the implant/replica platform, 1 and 2 (D1z), 1 and 3 (D2z), and 1 and 3 (D3z) were measured to get the inter implant distance in the Z-axis [Figures 12 and 13].

Figure 6: Syringable bis-GMA material

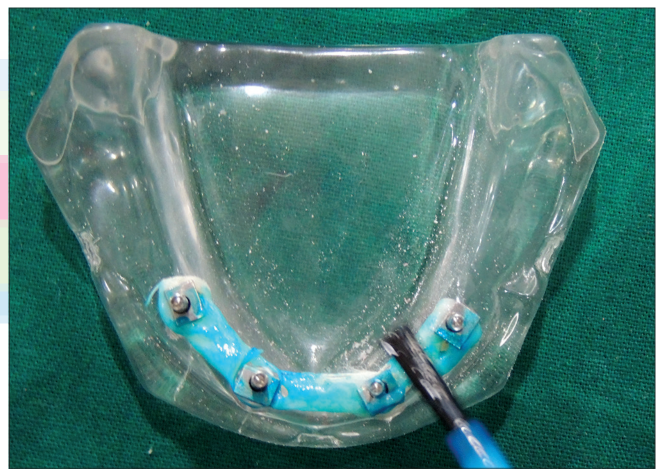


Figure 7: Application of polyether adhesive

Figure 8: Completed impression

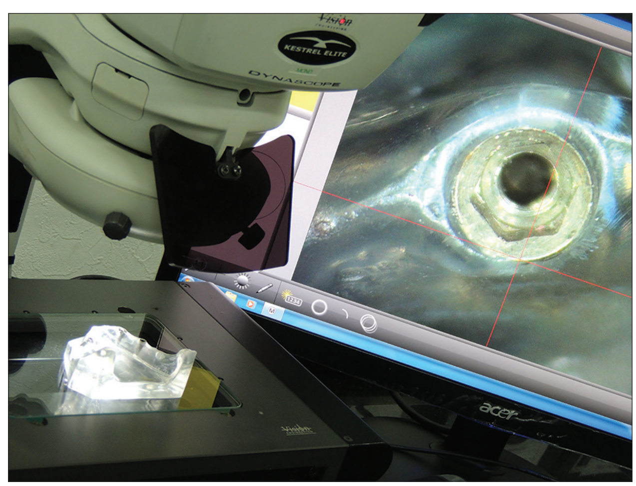


Figure 9: Magnified image of each implant in Dynascope-Vision Engineering

The angular difference between the implant and replica to the base of cast were evaluated using a co-ordinate measuring machine (CMM – TESA Microhite 3D, TESA Technology). The angle formed between the axis of implant and replica to the base of the model and cast, respectively, to the horizontal plane were recorded as angles 1, 2, 3, and 4 for the implants and replica [Figure 14].

The models were measured 5 times for each reading and the mean value was considered. All the measurements were made by a single operator to avoid inter operator error.

Statistic analysis

The measurements were tabulated and they were statistically analyzed and inference was obtained. A factorial analysis of variance using ANOVA was used for statistical analysis and $P < 0.05$ was considered as a significant. *Post-hoc* TESTS-homogeneous subset gives the difference between the groups based on which subset the group falls.

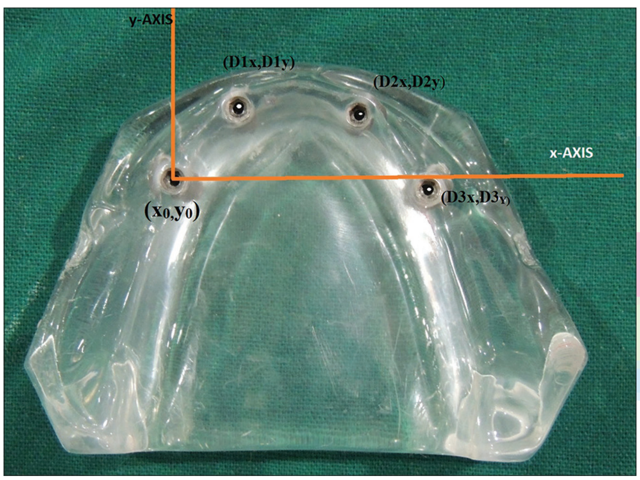


Figure 10: Inter implant distances in X and Y axis D1x and D1y – distance between implant/replica 1 and 2 in X and Y axis, respectively, D2x and D2y – distance between implant/replica 1 and 3 in X and Y axis, respectively, D3x and D3y – distance between implant/replica 1 and 4 in X and Y axis, respectively

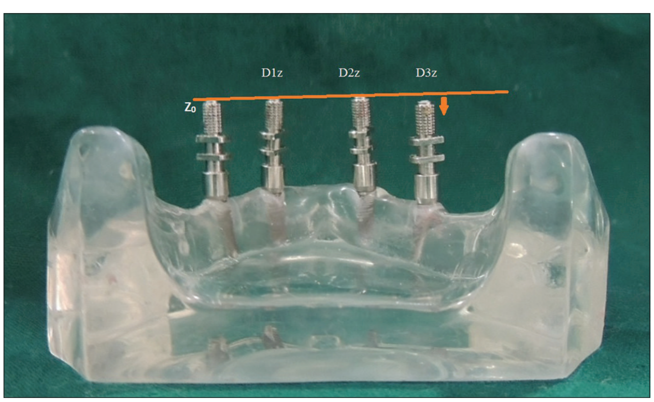


Figure 12: Inter implant distances In Z-axis D1z – distance between implant/replica 1 and 2 D2z – distance between implant/replica 1 and 3 D3z – distance between implant/replica 1 and 4

RESULTS

X-axis

The difference in inter implant distance in x-axis ranged from 116 μm to 16 μm for impressions with resin splinted copings, 33–4 μm for impressions with bis-GMA splinted copings. The differences in D1x (distance between implant replica 1 and 2), D2x (distance between implant replica 1 and 3), and D3x (distance between implant replica 1 and 4) for both the test groups were not statistically significant when compared with the reference model values [Tables 1 and 2 and Graph 1].

Y-axis

The difference in inter implant distance in Y-axis ranged from 216 μm to 180 μm for impressions with resin

Figure 11: TESA microhite two dimension

Figure 13: Co-ordinate measuring machine (CMM – TESA Microhite 3D, TESA)

splinted copings, 398–926 μm for impressions with bis-GMA splinted copings. Maximum differences were seen in D3y (distance between implant replica 1 and 4) values in Group B. A similar trend in dimensional distortion was evident in all the groups except that the amount of distortion varied within the groups [Tables 3 and 4 and Graph 2].

Z-axis

The difference in inter implant distance in Z-axis ranged from 1.1 mm to 42 μm for impressions with resin splinted copings, 1.008 mm to −330 μm for impressions with bis-GMA splinted copings. The analysis shows that the *P* value for the D1z, D2z is <0.05, and for D3z is >0.05. *Post-hoc* range tests shows that reference group significantly

Table 1: Comparison of inter implant distance in X-axis (values in mm)

Group	D1x		D2x		D3x	
	Mean	SD	Mean	SD	Mean	SD
Reference	9.15	0.00	26.04	0.00	35.84	0.00
Group A	9.26	0.34	26.13	0.36	35.85	0.13
Group B	9.48	0.07	26.34	0.06	35.84	0.13
F statistics	3.52		2.65		0.03	
P	0.063		0.111		0.970	

SD: Standard deviation

Table 2: Difference in inter implant distance in X-axis (values in mm)

Group	ΔD1x		ΔD2x		ΔD3x	
	Mean	SD	Mean	SD	Mean	SD
A	0.116	0.338	0.084	0.364	0.016	0.131
B	0.330	0.072	0.298	0.054	0.004	0.129

ΔD1x: D1x of the test group - D1x of the reference model, ΔD2x: D2x of the test group - D2x of the reference model, ΔD3x: D3x of the test group - D3x of the reference model. SD: Standard deviation

Table 3: Comparison of Inter implant distance in Y-axis (values in mm)

Group	D1y		D2y		D3y	
	Mean	SD	Mean	SD	Mean	SD
Reference	9.95	0.00	9.02	0.00	1.56	0.00
Group A	9.74	0.32	8.81	0.47	1.38	0.58
Group B	9.55	0.12	8.27	0.24	2.49	0.21
F statistics	5.04		7.91		13.97	
P	0.026*		0.006**		0.001**	

*Significant at 5%, **Significant at 1%. SD: Standard deviation

Table 4: Difference in inter implant distance in Y-axis (values in mm)

Group	ΔD1y		ΔD2y		ΔD3y	
	Mean	SD	Mean	SD	Mean	SD
A	−0.210	0.323	−0.216	0.475	−0.180	0.578
B	−0.398	0.121	−0.752	0.246	0.926	0.208

ΔD1y; D1y of the test group - D1yof the reference model, ΔD2y: D2y of the test group - D2y of the reference model, ΔD3y: D3y of the test group - D3y of the reference model. SD: Standard deviation

differs with Group A and Group B as they fall in different subsets. Both the Group A and B showed differences in similar range [Tables 5 and 6 and Graph 3].

Implant angulation in the Z-axis to the horizontal plane

It plane ranged from −6.78° to −7.21° for the resin splinted group and −3.78° to −5.07° for the bis-GMA splinted group. There was significant difference between the angles (1,

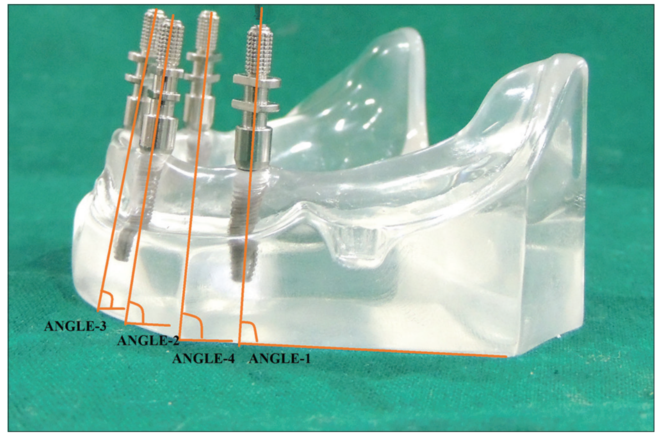
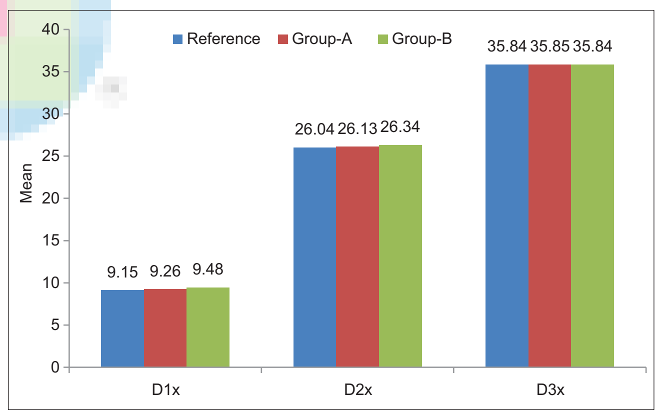
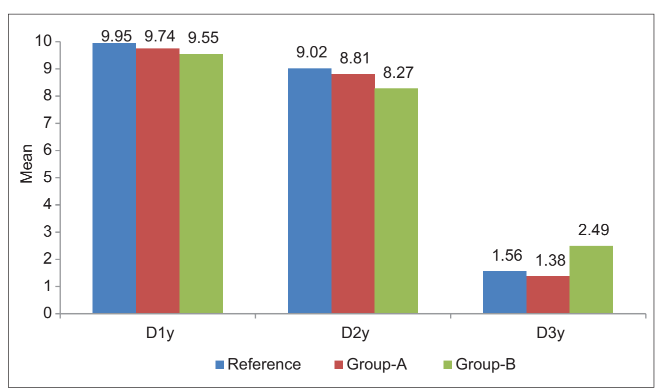


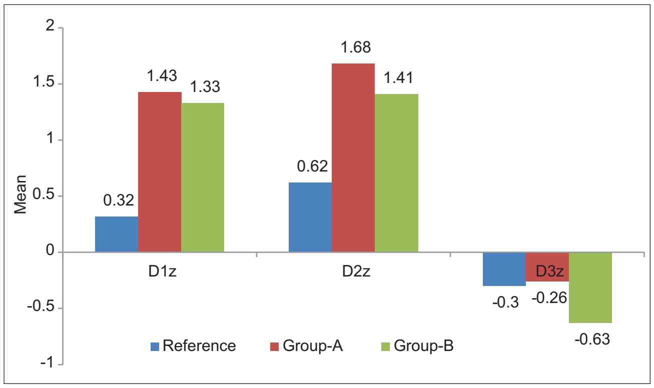
Figure 14: Angulation of implants to the horizontal plane angle 1 - the angle formed between the implant and replica. 1 to the base of the reference model and master cast angle 2 - angle formed between the implant/replica 2 to the base angle 3 - angle formed between the implant/replica 3 to the base angle 4 - angle formed between the implant/replica 4 to the base



Graph 1: Comparison of inter implant distance in X-axis (values in mm)



Graph 2: Comparison of inter implant distance in Y-axis (values in mm)



Graph 3: Comparison of inter implant distance in Z-axis (values in mm)

Table 5: Comparison of Inter implant distance in Z-axis (values in mm)

Group	D1z		D2z		D3z	
	Mean	SD	Mean	SD	Mean	SD
Reference	0.32	0.00	0.62	0.00	−0.30	0.00
Group A	1.43	0.46	1.68	0.65	−0.26	0.51
Group B	1.33	0.13	1.41	0.23	−0.63	0.43
F statistics	24.53		9.61		1.38	
P	<0.001**		0.003**		0.290	

*Significant at 5%, **Significant at 1%. SD: Standard deviation

Table 6: Difference in inter implant distance in Z-axis (values in mm)

Group	ΔD1z		ΔD2z		ΔD3z	
	Mean	SD	Mean	SD	Mean	SD
A	1.108	0.463	1.060	0.648	0.042	0.505
B	1.008	0.131	0.786	0.228	−0.330	0.433

ΔD1z: D1z of the test group - D1zof the reference model, ΔD2z: D2z of the test group - D2z of the reference model, ΔD3z: D3zof the test group - D3z of the reference model. SD: Standard deviation

Table 7: Comparison of implant angulation to horizontal plane in Z-axis (in degrees)

Group	Angle 1		Angle 2		Angle 3		Angle 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Reference	86.44	0.00	81.46	0.00	81.24	0.00	83.40	0.00
Group A	79.66	2.41	74.25	2.28	73.54	2.67	76.60	2.45
Group B	82.65	2.77	77.68	3.71	76.17	2.34	79.00	2.74
F statistics	12.86		10.30		18.24		13.20	
P	0.001**		0.002**		<0.001**		0.001**	

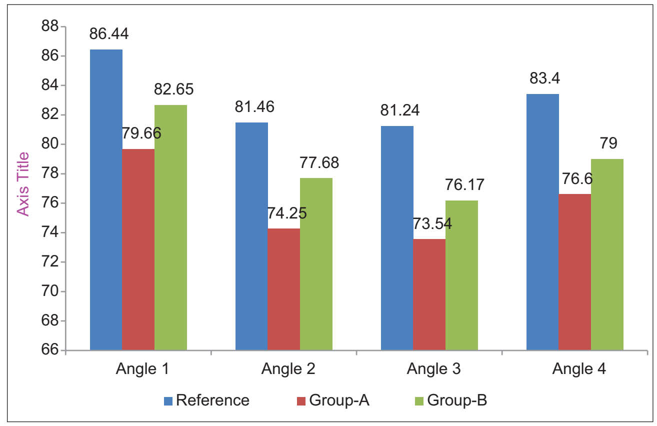
*Significant at 5%, **Significant at 1%. SD: Standard deviation

Table 8: Difference in implant angulation to horizontal plane in Z-axis (values in degrees)

Group	ΔAngle 1		ΔAngle 2		ΔAngle 3		ΔAngle 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	−6.78	2.41	−7.21	2.28	−7.70	2.67	−6.80	2.45
B	−3.79	2.77	−3.78	3.71	−5.07	2.34	−4.40	2.74

ΔAngle 1: Angle 1 of the test group - Angle 1 of the reference model, ΔAngle 2: Angle 2 of the test group - Angle 2 of the reference model, ΔAngle 3: Angle 3 of the test group - Angle 3 of the reference model, ΔAngle 4: Angle 4 of the test group - Angle 4 of the reference model. SD: Standard deviation

2, 3, and 4) of Group A and B to the reference model [Tables 7 and 8 and Graph 4].



Graph 4: Comparison of implant angulation to horizontal plane in Z-axis (in degrees)

DISCUSSION

The impression which allows replication must be accurate so that the resulting master cast precisely duplicates the clinical situation. Most research indicates that direct techniques produce less distortion than indirect techniques.[16,17,19,24,25] Because splinting with acrylic resin has yielded conflicting results.,[22,24,26-29] This is an attempt made to evaluate the reliability of bis-GMA (Pro-temp 4) as splinting material. Polyether has been advocated as an impression material for multiple implant-supported prosthesis for edentulous patients.[16,17,24,28] Medium-body polyether was used as the impression material.

The overall accuracy of the impression depends on all the four parameters in the X, Y, Z axis, and angulation of implant/replicas axis to its horizontal plane.

Rotation of impression copings in the impression during fastening of the implant analog is one of the drawbacks of the direct impression technique. In an absolute distortion analysis, an external reference point is used, while in relative distortion analysis one implant/replica is used as reference for measuring distortion. Because the prosthesis connects all the implant together, the amount of strain on the implant is related to the relative positions of the implants to one another.[30] Therefore, relative distortion analysis was done in this study by measuring the inter implant distances and angulations in reference to replica no. I.[30]

The errors in the resin splinting group could be attributed to the minimal shrinkage of the pattern resin used and the technique of splinting. Since the splint was sectioned in between the copings and then reunited, it could have minimized the polymerization shrinkage. Therefore, the amount of resin used for initial splinting could have not influenced the inaccuracy, whereas the dimension of the section made could have influenced the accuracy as it was joined again with resin before making impression. Further research on the dimensions of the splint and the dimensions of the section would shed light on the influence of resin shrinkage on the accuracy of impression. Also, the technique of resin splinting has differed among various studies done so far.[18-24]

Since bis-GMA (Pro-temp 4) has not been tested for accuracy as a splinting material, data regarding the accuracy of this material for splinting purpose is lacking. Thus, the values obtained for these materials in this study have to be compared with the values obtained with the resin splinting group only (since enormous studies had been conducted for the resin splinted copings). The range of differences obtained in bis-GMA splinted group in all the axis was almost in the similar range when compared to the resin splinted group. In X and Y axis both the Groups A and B exhibits no differences with the reference model. However, in Z-axis and the implant angulation to the horizontal plane, both the Groups A and B exhibited significant differences with the reference model in the similar range of difference. These differences could be attributed to the rigidity of the splinting material that was used to prevent the movement of copings in the vertical dimension during connection of the implant replica to the impression coping.[17,24] This *in vitro* study gives the amount of rotational distortion of impression copings in the Z-axis, which can occur when multiple implant impressions were made with polyether showed little discrepancies. From these data obtained, the inference of the study might probably application of polyether adhesive, rigidity of polyether impression material, rigidity of the splinting materials, tolerance between implant components and torque employed during fastening of the implant replica could determine, either individually or collectively the extent of distortion.[26-28,30]

Although splinting might rigidly hold the impression copings together, the time consumed for impression making is considerably greater when compared to the nonsplinting impression technique. This preliminary effort to study is the accuracy of master cast obtained using direct impression technique with different splinting materials has yielded positive results especially in relation to the use of bis-GMA (Pro-temp 4 – syringable temporary crown material), so this material can be used as the splinting material in lesser time in a more comfortable syringable mode. Thus, further research on the use of this material for splinting purpose might be of use to enhance the accuracy of impression techniques. The results obtained in this study are *in vitro* and so future clinical studies are required to evaluate the effect of intra oral conditions on the materials used for splinting.

CONCLUSION

The following conclusions were arrived within the limitations of this *in vitro* study, which evaluated the accuracy of master cast using direct implant impression techniques with conventional and newer splinting material for multiple implant impression.

- On comparison of the accuracy of implant impressions made by direct technique using resin splinted impression copings and bis-GMA splinted impression copings yielded master casts which had their readings very close to the reference model and within the clinical limits
- Both the splinting material showed the same amount of variation from the reference model and these splinting materials were statistically similar to each other and falls in same homogenous subsets in all the three dimensional X, Y, and Z axis
- Thus, both the splinting material exhibit similar accuracy in impression, so bis-GMA (Pro-temp 4 3M ESPE) as a splinting material is easy for handling, less time consuming, less technique sensitive, readily available material in clinics, and more rigid material can be used. However, selection of impression technique can be based only on the clinical situation and the personal clinician's choice.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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