DOI: 10.21608/adjalexu.2022.150446.1297

DIGITAL ASSESSMENT OF POSITIONAL ACCURACY OF DIFFERENT SPLINTING MULTIIMPLANT IMPRESSION TECHNIQUES: AN IN VITRO COMPARATIVE STUDY

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ABSTRACT

INTRODUCTION: Splinting of multiple implants during impression with the most accurate material to reproduce their intraoral relationship is deemed necessary for achieving passively fitting prosthesis.
OBJECTIVES: To assess positional accuracy of multiimplant impressions for completely edentulous arches obtained by a 3D printed splint and compare the results obtained with those obtained with conventional methods.
MATERIAL AND METHODS. One mandibular epoxy model with 4 parallel implants was used as master reference model. A total of 24 (n=24) open tray impressions were done using a custom-made tray and were poured in dental stone. Eight impressions were done with 3D printed splint (group I), 8 were done with the conventional splinting method (group II), and 8 were done with sectional splinting method (group III). Four impression posts were attached to each cast, and all casts were scanned using a desktop scanner. Surface scans for the 3 groups were superimposed with the scan of the master reference model. The positional accuracy of each post was compared with the reference model to assess positional deviations.
RESULTS: Models of group I showed lower positional deviation compared to other groups. No statistically significant differences were found between the 3 impression techniques regarding positional accuracy of the implants.
CONCLUSIONS: 3D printed splint method can be used as an alternative to conventional splinting techniques.
KEYWORDS: Multi-implant impression, splinting technique, 3D printed splint.
RUNNING TITLE: Digital Assessment of Different Multi-implant impression techniques.

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INTRODUCTION

Passive fit of screw retained implant prosthesis is an important determinant of its long-term success (1, 2). Complications like screw loosening, progressive marginal bone loss, fatigue fractures of the prosthodontic components and loss of osseointegration may all be attributed to improper fit of the restoration (3,4).

Multiple implant impression requires extreme care to precisely transfer the relationship between fixtures to the working cast. Due to lack of periodontal ligaments, minor errors could lead to misfit of the superstructure that would transfer stress to the surrounding bone leading to failures (5-7). The accuracy of multiimplant impressions is affected by splinting technique used for impression, the number of implants, implant angulations, implant design, the rigidity of the impression trays, impression materials used, and dental stone expansion (8-11).

Literature has indicated that polyvinylsiloxane (PVS) and polyether (PE) are the recommended impression materials of choice for multiple implant impressions, but no conclusive evidence exists regarding which is more accurate (12-15). PE has been found to produce better results in terms of implant cast accuracy and abutment framework interface gaps than PVS (6).

Custom open trays are preferred over closed trays for implant-assisted complete dental prostheses as they are more accurate (16, 17). The splinting and polymerization shrinkage of splinting material are 2 of the most important factors when making impressions for multiple implants, especially for 4 or more implants in the dental arch. (18, 19). Conventional splinting method with resin and dental floss is the most reliable method of splinting multiimplant impressions (20). To ensure maximum accuracy, some authors emphasized the importance of splinting impression posts together intraorally before making an impression and some authors sectioned the splint material leaving thin spaces and rejoined them with a minimal amount of the same material to minimize polymerization shrinkage. However, inconsistent results have been obtained (21, 22).

The use of 3D printed splints can reduce the recorded shrinkage error of resin splinting material (23,24). However, the accuracy of 3D printed splints in multiimplant impressions for complete edentulous arches has not yet been reported. This study aimed to evaluate whether using 3D printed splint could be an alternative to conventional resin splinting method on bases of accuracy. The null hypothesis was that the 3D printed splints will have insignificant results compared to conventional splinting impression techniques in terms of accuracy of implant position transfer.

MATERIAL AND METHODS

This in vitro study was conducted on 24 open tray impressions divided equally to 3 groups based on splinting method. Group I; 3D printed splint bar (n=8), group II; conventional resin splinting method (n=8) and group III; sectional splinting resin method (n=8). Sample size was calculated using G. Power 3.1.9.2 software (25) in reference to Liu et al (5) who aimed to assess the 3D accuracy of multi-implant impressions for complete arches obtained using 3D printing technology. Based on the study and by adopting a power of 80% to detect a standardized effect size in positional accuracy (d=0.765) (medium-sized standardized effect size), and level of significance 95% (a=0.05), the minimal required sample size was found to be 8 models per group. Since the number of groups is 3, the total sample size was calculated to be 24 impressions.

One epoxy mandibular complete edentulous model with gingival mask (Ramses Medical Products; Alexandria, Egypt) was used as a master reference model in this study. The model was initially scanned with cone beam computed tomography machine (X-Mind TRIUM; Acteon, USA) to obtain radiographic data. Implant planning software (3Diagnosys 4.2; 3DIEMME, Italy) was used for planning 4 parallel implants positions, surgical guide and 3D splint bar (Fig. 1).

The 3D splint bar was designed with sleeve-like rings around every impression post. The inner diameter of each ring was 7.5 mm allowing uniform space of 1 mm around the impression posts to facilitate seating of the splint and to act as reservoir for added resin to connect the splint with the posts during impression procedure. The outer diameters of the rings were 10.5 mm keeping a uniform, 1.5 mm, thickness of the splint. The designed surgical guide and 3D splint bar were printed in surgical guide resin (Surgical Guide Resin V1; formlabs, USA) using 3D printer (Formlabs Form 2; formlabs, USA) (Fig. 1).

Four dummy implants 3.6×10 mm (Dentium superline; Dentium Co. Ltd, Korea) were inserted in canines and second premolars with the surgical guide. Six landmarks; 2 at the anterior part of the model and 2 on each side were engraved on the ridge to aid in surface registration (Fig.1).

For impressions with 3D printed splint bar of group I, (5) open tray implant level impression posts were tightened to a maximum of 5 Ncm. The 3D printed splint bar was seated leaving 3 mm below the bar to allow space for impression material. Bar was connected to the posts with splinting resin (Duralay; Reliance Dental, USA). Acrylic custom tray and PE impression material (Impregum F; 3M ESPE, USA) were used to make the impression. After complete setting of PE, the screws of the impression posts were released and the impression tray was removed. Four implant analogues were connected to impression posts and impression was poured with type IV dental stone to obtain a cast (Fig. 2).

For impressions with conventional resin splinting method of group II (20), impression posts were tightened to the reference model and were connected with dental floss. Splinting resin was applied on the floss to splint the impression posts. The impression procedure was continued as in group I and a cast was obtained (Fig. 3).

For impressions with sectional splinting resin method of group III (21), impression posts were tightened to the reference model, connected by dental floss, and splinted with splinting resin. The splint was sectioned and left for 24 hours anticipating for the dimensional changes. The resin sections were rejoined with splinting resin, impression procedure was continued as in group I, and a cast was obtained (Fig. 3).

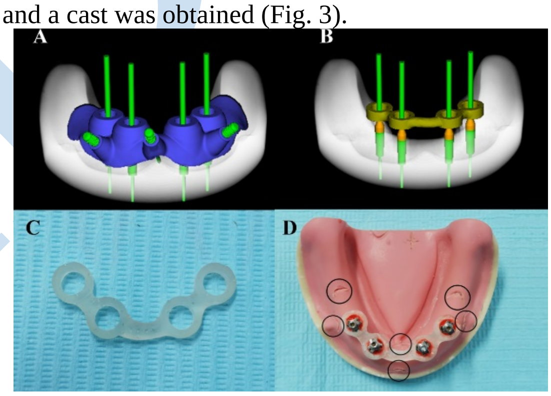

Figure (1): A, Surgical guide planning. B, 3D splint bar planning. C, 3D Printed resin splint bar. D, Master reference model with landmarks.

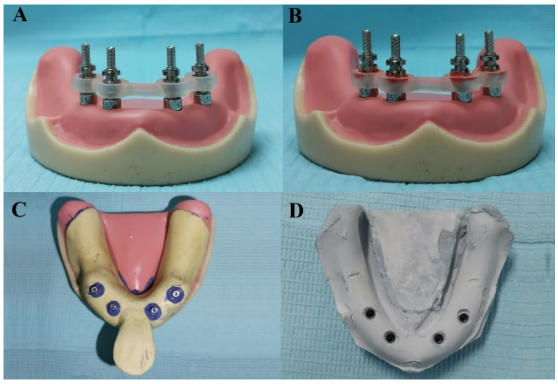

Figure (2): A, Insertion of 3D printed splint bar in position. B, 3D splint bar connected to impression posts with splinting resin. C, Impression tray seated in place. D, The produced cast.

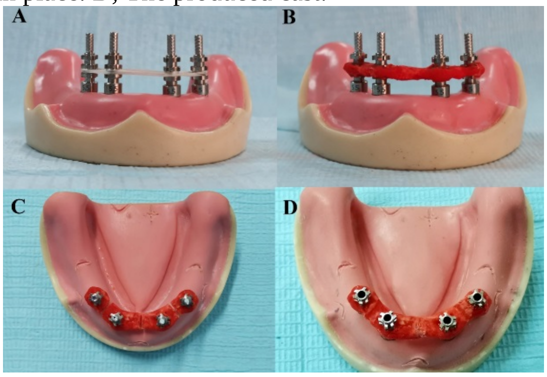

Figure (3): A, Impression posts connected with dental floss. B, Impression posts splinted by resin. C, Sectioned resin splint. D, Resin splint rejoined after 24 hours.

A new set of impression posts were tightened to the master reference epoxy model during scanning with the desktop scanner (inEos X5; Dentsply Sirona, USA). The same set was used during scanning of all produced stone casts of the 3 groups. Models were sprayed by aluminum oxide powder and were scanned. Surface registrations were done for all produced stone casts with the reference model with best fit algorithm using the edentulous ridge and the 6 marks on the scans as reference, excluding the impression posts. Standard tessellation language (STL) dataset of the master reference model was imported into CAD software program (Autodesk meshmixer; Autodesk Inc, USA) to design a rectangle at the level of the neck of the implant with fixed orientation to the impression post. At the center of the superior surface of the rectangle, a cone tip was created.

Using CAD measuring software (GOM inspect; GOM GmbH, Germany), 4 rectangles were registered for all 4 posts. The same procedure was repeated for all posts in all produced casts (Fig. 4). Positional deviations between the cone head point of every implant and that of the same implant on the reference model was done in XYZ axes. Horizontal and vertical angles of deviation for each post compared to the reference model were calculated. All data were collected and sent for statistical analysis.

Data were analyzed using SPSS version 25. Normality was checked using Shapiro Wilk test and box plot. Comparisons were done using Kruskal Wallis test, followed by post hoc comparisons when needed. Significance level was set at $P \leq .05$.

RESULTS

When comparing positional deviation among the 3 study groups at XYZ axes to the reference model, results showed that there were statistically nonsignificant differences of the x and z axes (P=.167, P=.578) among all the studied groups, while there was a statistically significant difference on the y axis (P=.008) (Table 1). There were statistically nonsignificant differences when comparing the groups to the reference model in the combined XYZ axes (P=.202). Group II showed the lowest mean value of combined positional deviation (0.002 ±0.02) (Fig. 5).

The angular deviation of impression posts of the 3 study groups at the horizontal direction showed that group I had least horizontal angular deviation (2.88±1.05), while group II (3.25±1.01) and group III (3.85±0.39) had higher statistically nonsignificant values (P=.104). Angular deviation among the study groups at the vertical direction showed that group I (0.33±0.11), II (0.49±0.15) and III (0.43±0.11) had statistically nonsignificant differences (P=.062). Group I showed the least vertical angular deviation (Table 2) (Fig. 6).

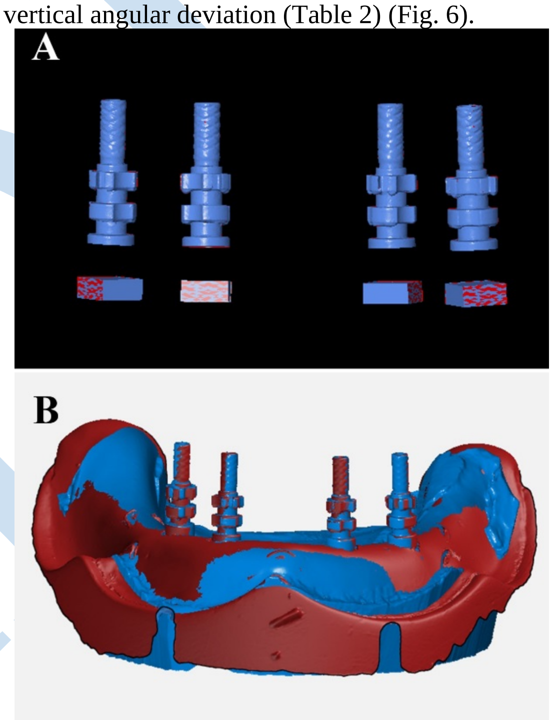

Figure (4): A, Master reference model posts with rectangles. B, Produced model scan registered on master reference model scan.

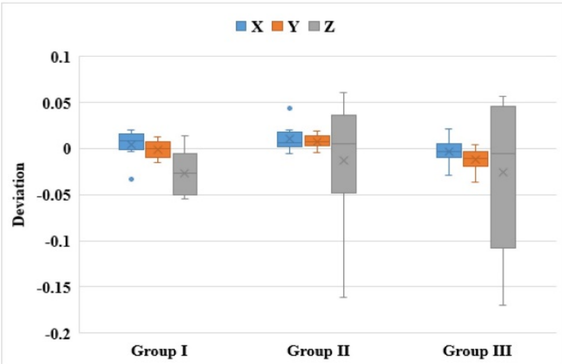

Figure (5): Positional deviation of the 3 study groups at the XYZ axes.

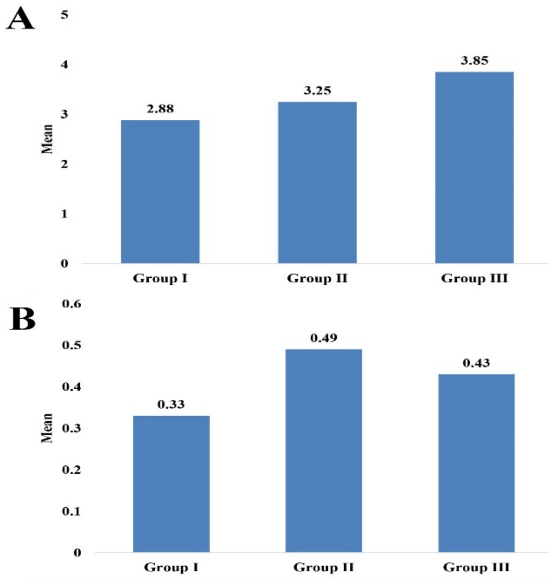

Figure (6): Angular deviation of the 3 study groups compared with master reference model. A, Horizontal angular deviation. B, Vertical angular deviation.

Table (1): Positional deviation (mm) among the 3 study groups at the XYZ axes.

	Group I (n=8) Mean ± SD	Group II (n=8) Mean ± SD	Group III (n=8) Mean ± SD	X^2 Test	*P*
X	0.005 ± 0.0)	0.011 ± 0.02	-0.003 ± 0.01	3.850	.167
Y	-0.001 ± 0.00)	0.008 ± 0.007	-0.012 ± 0.012	9.680	**.008***
Z	-0.026 ± 0.02	-0.013 ± 0.07	-0.025 ± 0.08	1.095	.578
Combined XYZ	-0.007 ± 0.01	0.002 ± 0.02	-0.01 ± 0.03	3.200	.202

SD, standard deviation
*statistically significant at $P \le .05$
(-) used to indicate reversed direction of deviation compared to axis

Table (2): Angular deviation (degrees) among the study groups at the horizontal and vertical directions.

	Group I (n=8) Mean ± SD	Group II (n=8) Mean ± SD	Group III (n=8) Mean ± SD	X^2 Test	*P*
Horizontal angle	2.88 ± 1.05	3.25 ± 1.01	3.85 ± 0.39	4.055	0.132
Vertical angle	0.33 ± 0.11	0.49 ± 0.15	0.43 ± 0.11	5.178	.052

SD, standard deviation

DISCUSSION

This study revealed that the 3 techniques under study had a nonsignificant effect on the positional accuracy of the multiimplant impressions. As a result, the null hypothesis was confirmed.

Many studies have shown no difference in the accuracy of PE or PVS, and both materials are recommended for implant impressions (12,14). However, PE material was the material of choice for evaluating the differences among impression techniques in the present study, as it shows reduced permanent deformation of the impression material caused by the stress induced between the material and the impression posts at time of retrieval (13,15). Additionally, PE has been found to produce better results in terms of implant cast accuracy and abutment framework interface gaps compared with PVS (6).

Implant level impressions with different types of splinting was selected to be evaluated in this study as solid splinting stabilizes impression posts when compared with nonsplinting types resulting in decreased variation in the relative implant positions especially in completely edentulous patients (9). Resin and dental floss technique is the most reliable method of splinting multiimplant impressions (20). Thus it was selected for the present study.

Shrinkage of splinting materials and micro movement between transfer posts and splinting materials has been reported to cause lower impression accuracy (7). Thus 3D printing technology was suggested in this study for fabrication of 3D splint bar for multiimplant impression assuming that it would be more advantageous in eliminating errors of conventional splinting through eliminating manual procedures and reducing the number of patient visits (8,9).

The results of the present study showed that the 3D printed splinting bar revealed the least, yet nonsignificant, positional deviations. This finding can be attributed to the uniform space for the splinting resin between the impression post and 3D splint bar achieved in the design. Additionally, 3D printing technologies were reported to have highly accurate dimensions of produced objects (5,23).

The 2 conventional splinting techniques of this study showed higher positional deviation compared with the 3D splint bar. This could be attributed to the unavoidable dimensional changes of the splinting resin during and after complete polymerization reported in literature (18,19).

This study did not consider the augmented negative effect of deviation caused by making preliminary impressions used in conventional methods (8,9). Therefore, the 3 splinting methods used in this study should be tested in clinical settings to find out if 3D printed splint bar impression technique built using an intraoral scanner would possess better results.

CONCLUSIONS

Based on the findings of this in vitro study, multiimplant impressions using 3D printed splinting bar could yield impression with comparable accuracy compared with that obtained with conventional splinting techniques, and with advantage of eliminating manual long procedures and reducing the number of patient visits.

CONFLICT OF INTEREST

The authors declare that they have no financial or personal conflicts of interest.

FUNDING STATEMENT

There was no special funding provided to the authors for this work.

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