EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 3431:3441, October, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Fixed Prosthodontics and Dental Materials

Submit Date : 06-06-2022 • Accept Date : 02-07-2022 • Available online: 01-10-2022 • DOI : 10.21608/edj.2022.141408.2124

DIGITAL EVALUATION OF A SIMPLIFIED TECHNIQUE FOR RESIN SPLINTING USED FOR MULTIUNIT IMPLANT RESTORATION IMPRESSIONS: AN IN-VITRO COMPARATIVE STUDY

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ABSTRACT

Objectives: This study aims to simplify the conventional resin-on-floss splinting technique and study the precision of this modified multiimplant impression technique.

Material and Methods: Twenty-four (n=24) impressions were done for one mandibular completely edentulous model with six implants placed at the canines, first premolars and first molars. Group I (n=12) used the sectional resin-on-floss splinting technique. Group II (n=12) used the simplified tray-resin splint technique. The reference model and casts were scanned. Obtained STLs were aligned. Virtual implants on each cast were compared to reference model measuring angular and positional deviations. All variables and were compared at p value <.05.

Results: Group I had significantly lower differences in angular deviations in vertical and horizontal axes of each implant except the left first molar implant, vertically, and the left first premolar implant, horizontally. The overall angular deviations of all implants were significantly lower in group I at the vertical axis. Group I had significantly lower positional deviations in XY axes of each implant except the left first molar implant. Group I showed significantly lower values on the left canine and left first premolar implant in the Z axis. The overall positional deviations of each implant of group I were significantly lower on the left canine and right first molar implants. The overall positional deviations of all implants were significantly lower in group I at the XY axes.

Conclusions: Conventional resin-on-floss technique showed less deviation values. Values of both techniques remained within the accepted level of clinical misfit values proposed in literature.

KEYWORDS: Open tray implant impression, positional accuracy, resin-on-floss splinting, simplified splinting technique, tray-resin splinting.

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INTRODUCTION

Achieving ultimately passive fitting implant prostheses is not possible but minimizing misfits at the implant-prostheses interface is still mandatory and achievable[1,2]. A passively fitting implant prosthesis is crucial to maintain mechanical and biological integrity of the implant system especially in multiple implant restorations. On the long term, prosthesis misfit directly affects the success of any implant restoration especially fixed ones[3,4]. Complications like loss of osseointegration, fractures of the components of the superstructure, abutment screw loosening, and marginal bone loss could all be a manifestation of improper fit of the prosthesis[5].

The prosthesis fitting precision starts at the impression stage and keeps building throughout all construction steps. Cumulative dental laboratory errors contribute to cause misfits in implant restorations[6]. Various aspects of multiimplant impression accuracy have been studied thoroughly in literature including technique used, material of the impression, implant angulation, implant depth, and method of splinting of impression copings. In case of multiunit implant impressions, no strict guidelines would recommend definite material or technique[2].

When obtaining a conventional impression for an implant restoration, polyvinylsiloxanes (PVS) and polyethers (PE) were found to be excellent[7]. However, PE was suggested to be more suitable for edentulous dental arches[8]. Regarding the technique for a conventional impression, open tray and closed tray techniques are available. Greater accuracy has been reported when an open tray technique is performed with splinting of the impression copings especially for multiunit implant prostheses[9-11].

Many splinting techniques and splinting materials were studied in literature[12,13]. Auto polymerizing acrylic resins like Duralay and photopolymerizing resins like flowable composite were both used as splinting materials[2]. The inherent polymerization shrinkage of the auto polymerizing resins causes distortion of the splint which in turn would adversely affect the accuracy of the implant restoration especially when made on four or more implants[14]. A total shrinkage of 7.9% was reported by Gibbs et al after 24 h[15]. In addition, 80% of that shrinkage took place after the first 17 minutes. To ensure higher precision, Kim et al[16] and Choi et al[17] tested splinting of the impression copings with auto polymerizing acrylic resin. Cutting and reconnecting was done for the splints to minimize the polymerization shrinkage. They proposed cutting the splint and reconnecting the cut parts after 24 h would minimize the polymerization shrinkage. However, inconsistent results have been obtained[2,15].

Despite the high precision values obtained by resin on dental floss splinting[5], this procedure, especially in case of full-arch implant restorations, are not ideal because of the extended working time and the need for a second appointment[18]. Other drawbacks were also evident including need for a custom tray with additional spacer to accommodate for the splint as well as the dental structures being recorded, and injection of the impression material underneath the splint is mandatory to ensure complete registration of the details beneath the constructed splint[19-22].

This study aims to assess the accuracy of a simplified splinting technique as an alternative to the resin-on-floss technique used for open-tray implant impressions. The null hypothesis of this study is that the modifications made in the technique would have no significant effect on impression accuracy compared to the conventional methods.

MATERIAL AND METHODS

This in-vitro comparative study aims to assess the accuracy of a simplified splinting technique as an alternative to the resin-on-floss technique used for open-tray implant impressions. The study was carried out on 24 open tray impressions made on the same epoxy model with six implants inserted with the aid of a surgical guide. The impressions were divided to two groups. Group I used the sectional resin-on-floss splinting method and group II used the modified tray-resin splint technique. A power analysis was performed with G*Power[23] to calculate the sample size for each group which was determined to be 12 assuming a 5% alpha error and 80% study power. This sample size was calculated in reference to Liu et al[24] and Al Quran et al[25].

One epoxy mandibular completely edentulous model was used in this study. The model was initially scanned with cone beam computed tomography to plan the position of the six prospective implants. Obtained data were imported in implant planning software (Blue Sky Plan; Blue Sky Bio) to virtually place six dental implants parallel to each distributed bilaterally in the arch at the canines, first premolars, and the first molars regions. A computerized surgical guide was designed, 3D printed, and was used for placement of six dummy implants 4 × 10 mm (Superline II; Dentium) in the epoxy model.

For each group, a custom acrylic tray was fabricated. For group I, the custom tray was spaced to accommodate the splinting resin bar and enough impression material. The openings made in the tray were at the level of the tightening screw of the impression copings (Figure 1). For group II, the tray was fabricated to closely adapt to the edentulous ridge leaving two mm space for the impression material. The openings made in the tray were leveled to the middle parts of the impression copings leaving the top part exposed above the tray level (Figure 2).

Open tray impressions of group I (n=12)

Six open tray impression copings were screwed with the torque wrench on the implants using 15 N/cm^2 to ensure proper fixation yet avoiding over-torquing the retention screw to its endurance limit. The copings were then connected by dental floss to carry the splinting resin. Splinting resin (Duralay; Reliance Dental) was applied to splint the impression copings securely. The splint was sectioned and kept for 24 hours. Thereafter, the thin spaces between sections were filled by resin (Figure 3). PE (Impregum™ F; 3M) was mixed and injected under the splint bar and the custom-made acrylic tray was filled with PE and was seated on the model (Figure 4). After setting of PE, the screws were released and the impression was retrieved. Implant analogues were connected to impression copings and a type IV dental stone was used to pour a cast. After pouring the cast, the impression material used for making the impression was weighed by the aid of a digital scale.

Open tray impressions of group II (n=12)

Open tray impression copings were screwed with the torque wrench on the implants using 15 N/cm^2. PE was mixed and filled in the custom-made tray, then was seated on the model. After setting, excess PE was cut to expose the top part of the impression copings (Figure 5). Copings were then splinted directly to the acrylic tray with the splinting resin (Figure 6). After polymerization, the screws were released, and the impression was retrieved. Implant analogues were connected to impression copings and a type IV dental stone was used to pour a cast. After pouring the cast, the impression material used for making the impression was weighed by the aid of a digital scale.

Positional accuracy evaluation

Before scanning, the same set of impression copings were screwed every time in the same order to their implants on the epoxy model and all produced casts (Figure 7 and 8). The retention screws were replaced after using for six times. This was done to omit any manufacturing or re-screwing errors that might arise from repeated screwing of the copings to the analogues[26,27]. All models were sprayed with aluminum oxide powder before scanning with desktop scanner (inEos X5; Dentsply Sirona). The obtained STL models were aligned to the epoxy model STL with local best fit match after selecting the edentulous arch in both STL scans as mutual reference (Figure 9). For each scan, six virtual implants were aligned to the impression copings using a digital library (Figure 10). The XYZ axes were oriented on each scan so that the X and Y axes faces the horizontal plane, and the Z axis faces the vertical plane. Using CAD inspection software (GOM Inspect; GOM GmbH), the center points of the virtual implant platforms on each cast were compared to those of the virtual implants on the epoxy model to measure the positional deviations in the XYZ axes (Figure 11). Angular deviations in vertical direction were calculated by measuring the angle between vertical lines traced on the hexagonal connection of each virtual implant on the produced cast compared to the epoxy model. Horizontal lines were traced on the virtual implant connection and the same method was followed to measure the horizontal angle of deviation (Figure 12).

IBM SPSS for Windows (Version 23.0) was used to analyze the data. All variables were checked for normality with descriptive statistics, plots (histogram and Q-Q plots), and normality tests. Means and standard deviations (SD) were calculated for all variables. Comparisons between the two study groups were done with independent samples t-test or Mann-Whitney U tests according to the variable normality. Significance was inferred at p value <0.05.

Fig. (1): Custom made tray of group I. The tray holes are made at the level of the screws heads.

Fig. (2): Custom made tray of group II. The tray is made to closely fit the ridge exposing most of the impression copings above the tray holes.

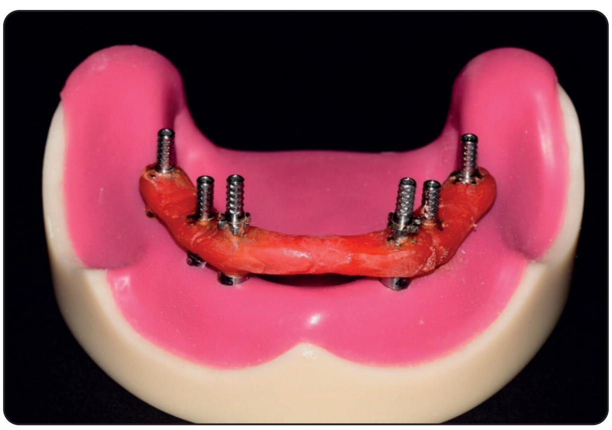

Fig. (3): Resin-on-floss splint rejoined after 24 hours.

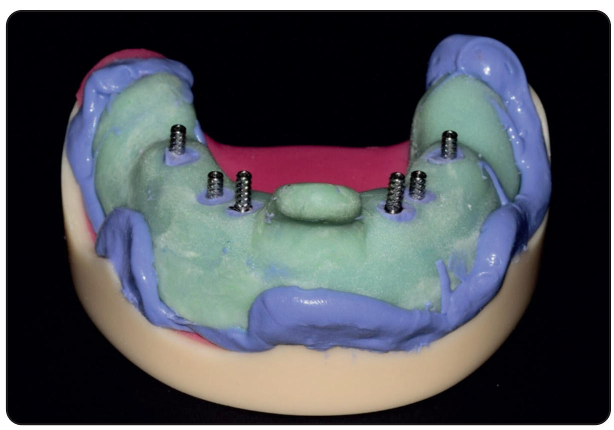

Fig. (4): PE impression made to capture the ridge area and enclose the splint underneath the tray.

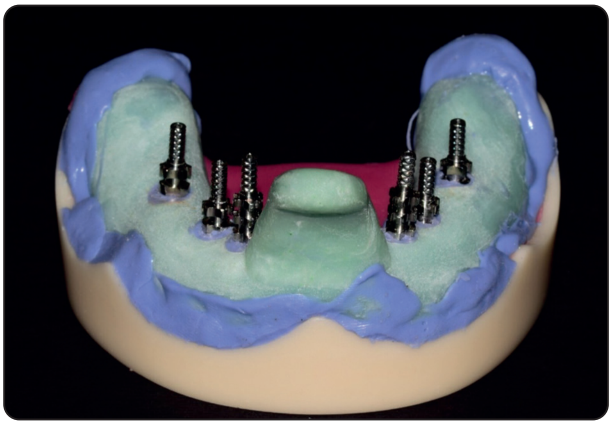

Fig. (5): PE impression capturing the ridge and leaving the coronal parts of the impression copings uncovered.

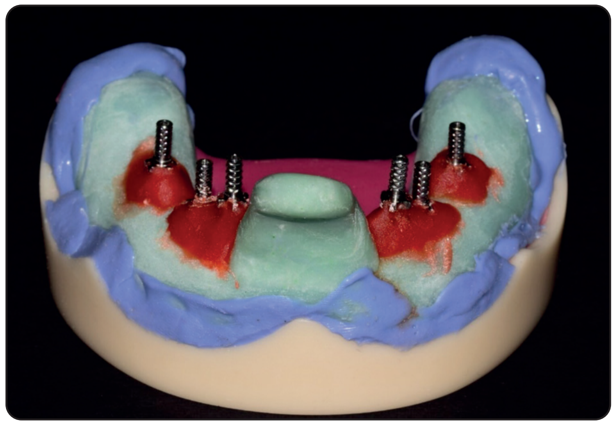

Fig. (6): Resin applied to splint the copings to the body of the impression tray.

Fig. (7): Reference epoxy model with copings in situ ready for scanning.

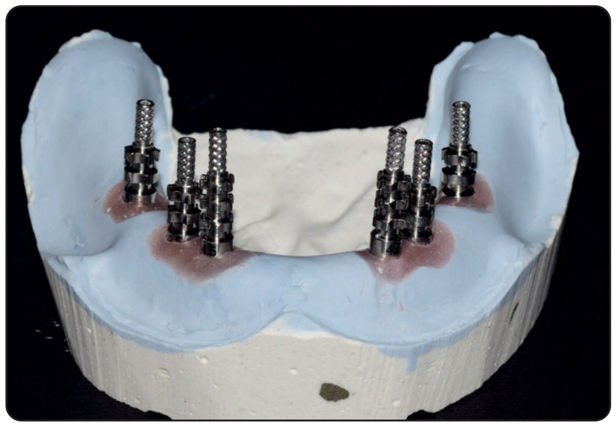

Fig. (8): A stone cast with copings in situ ready for scanning. Same set of copings used on all produced casts during scanning to exclude possible errors of manufacturing and omit effect of repeated screwing of implant components.

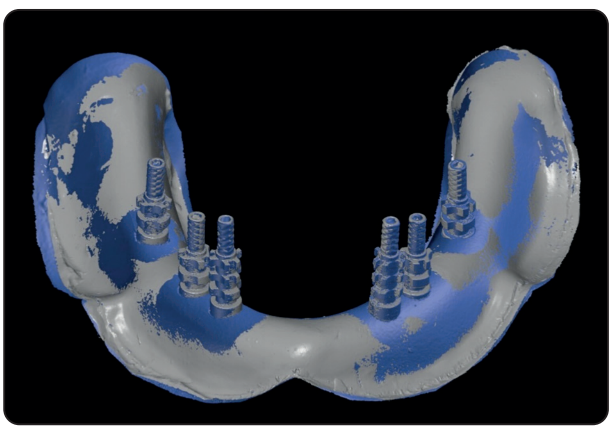

Fig. (9): Virtual models of each cast aligned to the reference model.

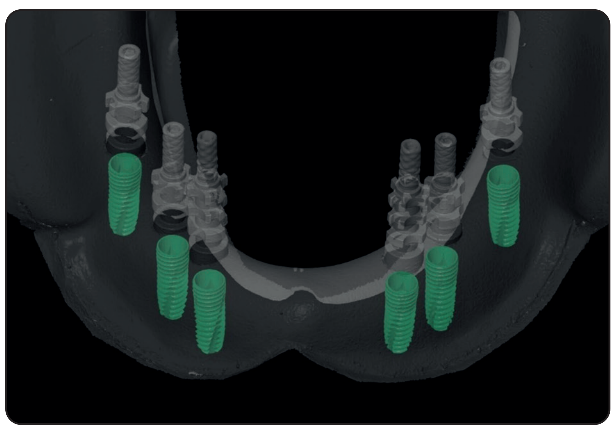

Fig. (10): Virtual implant analogues aligned to each impression post.

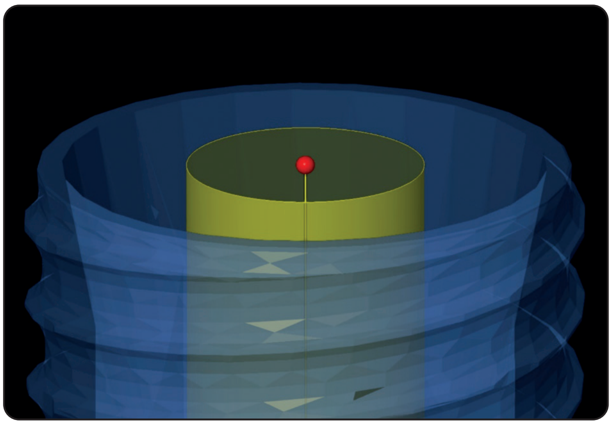

Fig. (11): Positional deviations in the XYZ axes. The center of the implant platform (red dot) determined and used to compare implants positional deviations in the XYZ axes

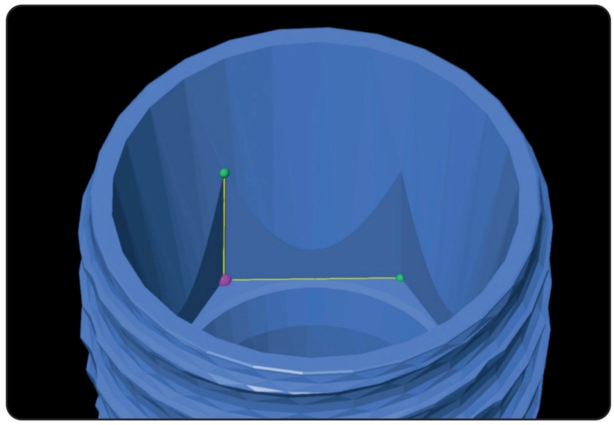

Fig. (12): Angular deviations in vertical and horizontal directions. Two lines (yellow lines) traced on hexagonal implant connection and used to calculate the angular deviation of each implant in the vertical and horizontal directions

RESULTS

Using the epoxy model virtual implant positions and angulations as reference, implants of each group were compared both individually and combined with their respective counterparts.

Table 1 shows a comparison of angular deviations in vertical and horizontal directions for each individual implant in the two study groups. Measurements are displayed in degrees. When comparing the mean angular deviations in the vertical axis of each implant individually, statistically significant differences on all implants was found except for the implant at left first molar (*P*=*.10*). Similarly, when comparing the mean horizontal angular deviations, statistically significant differences on all implants was found except for implant at the left first premolar (*P*=*.82*).

Table 2 shows a comparison of positional deviation in XYZ axes for each individual implant in the two study groups. Measurements are displayed in microns (μm). When comparing means of positional deviations of each implant individually in the horizontal XY axes, statistically significant differences were found on all implants except for implant of the left first molar (*P*=*.82*). When comparing means in the vertical Z axis, statistically significant differences were found on implants of the left canine (*P*=*.03*) and left first premolar (*P*=*.002*). When the overall (XYZ) positional deviations of each individual implant were compared, statistically significant differences were found on implants of the left canine (*P*=*.04*) and right first molar (*P*=*.048*).

Table 3 shows comparison of positional and angular deviations for all implants in the two study groups. When comparing the mean angular deviations in the vertical axis of all implants, a statistically significant difference was found (*P*=*.01*). When comparing their mean horizontal angular deviations, no statistically significant difference was found (*P*=*.77*). When comparing the mean positional deviations of all implants in the horizontal XY axes, a statistically significant difference was found (*P*<*.001*). When comparing them in the vertical Z axis, no statistically significant difference was found (*P*=*.38*). When the overall positional deviations of all implants were compared, no statistically significant difference was found (*P*=*.37*).

Table 4 shows comparison of impression material weight in the two study groups. When the mean values of impression material weights were compared, group II showed a statistically significant lower value (*P*<*.001*).

TABLE (1): Angular deviations in vertical and horizontal directions for each implant in the two study groups. Measurements are displayed in degrees.

Implant	Angle direction	Group I	Group II	P value
		Mean ± SD		
Left first molar	**Vertical [1]**	0.19 ±0.05	0.23 ±0.01	.10
	Horizontal [1]	0.55 ±0.05	0.64 ±0.03	**.004***
Left first premolar	**Vertical [1]**	0.13 ±0.04	0.27 ±0.06	**.001***
	Horizontal [1]	0.78 ±0.03	0.78 ±0.01	.82
Left canine	**Vertical [1]**	0.40 ±0.04	0.55 ±0.02	**<.001***
	Horizontal [1]	0.96 ±0.02	0.67 ±0.09	**<.001***
Right canine	**Vertical [1]**	0.17 ±0.06	0.51 ±0.04	**<.001***
	Horizontal [1]	0.27 ±0.04	0.52 ±0.06	**<.001***
Right first premolar	**Vertical [1]**	0.17 ±0.04	0.10 ±0.04	**.02***
	Horizontal [1]	0.21 ±0.03	0.09 ±0.03	**<.001***
Right first molar	**Vertical [1]**	0.15 ±0.04	0.10 ±0.02	**.01***
	Horizontal [1]	0.26 ±0.03	0.43 ±0.02	**<.001***

[1]: T-test was used. ****Statistically significant at p value <.05***

TABLE (2): Positional deviation in XYZ axes for each implant in the two study groups. Measurements are displayed in microns (μm).

Implant	Axis direction (μm)	Group I	Group II	P value
		Mean ± SD		
Left first molar	**XY [2]**	42.17 ±20.60	37.50 ±11.13	.82
	Z [2]	14.00 ±7.64	18.00 ±17.62	.82
	Overall [1]	68.00 ±22.25	70.67 ±23.53	.84
Left first premolar	**XY [2]**	12.83 ±11.92	62.83 ±7.10	**.002***
	Z [2]	49.00 ±11.17	9.00 ±5.37	**.002***
	Overall [1]	57.00 ±20.26	74.00 ±10.84	.10
Left canine	**XY [2]**	14.33 ±4.23	28.67 ±8.65	**.03***
	Z [2]	12.00 ±9.29	22.67 ±7.81	**.03***
	Overall [1]	28.00 ±8.53	37.33 ±2.73	**.04***
Right canine	**XY [2]**	22.83 ±2.29	39.50 ±6.34	**.002***
	Z [2]	49.33 ±15.13	37.00 ±24.61	.39
	Overall [1]	61.33 ±12.53	65.67 ±2.25	.44
Right first premolar	**XY [2]**	32.50 ±4.27	22.33 ±3.85	**.009***
	Z [2]	46.33 ±12.53	39.33 ±29.52	.82
	Overall [1]	69.67 ±7.81	49.00 ±21.09	.06
Right first molar	**XY [2]**	19.33 ±6.87	32.50 ±6.87	**.009***
	Z [2]	22.00 ±13.42	40.00 ±21.76	.13
	Overall [1]	38.33 ±11.32	51.00 ±7.80	**.048***

1: T-test was used, 2: Mann-Whitney U test was used. ****Statistically significant at p value <.05***

TABLE (3): Positional and angular deviations for all implants in the two study groups.

		Group I	Group II	P value
		Mean ± SD		
Overall average of all implants	**Vertical angle [1]**	0.20 ±0.10	0.29 ±0.18	**.01***
	Horizontal angle [1]	0.50 ±0.29	0.52 ±0.23	.77
	XY (μm) [2]	24.00 ±14.28	37.22 ±14.94	**<.001***
	Z (μm) [2]	32.11 ±19.92	27.67 ±21.91	.38
	Overall (μm) [1]	53.72 ±20.82	57.94 ±18.62	.37

[1]: *T-test was used,* [2]: *Mann-Whitney U test was used.* *Statistically significant at p value <.05

TABLE (4): Impression material weight displayed in grams (gm).

	Epoxy model	Group I	Group II	P value
		Mean ± SD		
Impression material weight (gm) [1]	-	16.17 ±0.75	8.17 ±0.75	**<.001***

[1]: *T-test was used.* *Statistically significant at p value <.05

DISCUSSION

The present study aimed to assess the simplified splinting technique and study its effect on the precision of open tray multiimplant impression procedures. Group I had significantly lower differences in angular deviations in vertical and horizontal axes of each implant except the left first molar implant, vertically, and the left first premolar implant, horizontally. The overall angular deviations of all implants were significantly lower in group I at the vertical axis. Group I had significantly lower positional deviations in XY axes of each implant except the left first molar implant. Group I showed significantly lower values on the left canine and left first premolar implant in the Z axis. The overall positional deviations of each implant of group I were significantly lower on the left canine and right first molar implants. The overall positional deviations of all implants were significantly lower in group I at the XY axes. Based on these results, the null hypothesis was accepted.

Duralay autopolymerizing resin was selected in this study as it is considered the most used splinting material(2,15). The resin-on-floss splinting technique used for group I was selected as control because it seems to show the highest accuracy among other conventional impression techniques for multiunit implant restorations(2,5,16,17, 25).

The results of this study showed that group I implants showed lower mean angular deviation values on most of the implants in both horizontal and vertical directions. These values were mostly significant when comparing each individual implant separately. When assessing all angular deviation values of both groups, it was found to be under one degree which seems to produce a clinical accepted misfit value(1).

When the overall means of the implant axes deviations were compared, it was significant at the vertical implants' axes. This finding seems logical from the physics point of view as the splinting points, which would act as pivot centers, of the impression copings of group II are to some extent higher in level giving higher chances for vertical angular deviations (Figure 3 and 6). In other words, splinting of the impression copings at a level closer to the implant platforms, which is the case in group I, would create less deviation in vertical angles.

The results of this study showed that on comparing each implant individually, most of group I implants had lower mean positional deviation values. This finding was significant at the XY axes only. It is also important to mention here that all positional deviation values of both groups remained under 75 μm. According to a Al Quran et al[25], a misfit value of less than 100 μm would be clinically acceptable. A systematic review of literature[1] also suggested a clinical misfit value of about 150 µm was considered acceptable. Accordingly, the tested techniques are expected to produce a clinical accepted misfit value. These results came in line with those present by Menini et al[4] who revealed a mean gap of 22 ± 23 μm up to 63 ± 59 μm when using traditional impression techniques.

When the overall means of the implant positional deviations were compared, it was significant in the XY axes and insignificant in both the Z axis and the overall XYZ axes values. This could be justified by the higher level of the pivoting centers of the impression copings in group II. This allowed more freedom in movement in the horizontal direction resulting in higher deviation at the XY axes. On the contrary, this freedom is very limited in the vertical Z axis when the copings were splinted to the impression tray as in group II. This explains why the Z axis positional deviations of group II were less in value when compared to group I as the splint bar of group I was free to move in the elastic impression material when the tray was pulled away from the model surface. In other words, fixing the impression copings to the tray itself would create less positional deviation in vertical axes.

This study showed that impressions made for group II consumed half the amount of impression material compared to group I. This means that greater dimensional changes are predicted for impression material used in group I. Additionally, greater freedom in movement is expected for the splinting bar used in group I during impression retrieval from the patients' mouths. These predictions added to the limitations of the resin-on-floss techniques[19-22] might favor using the suggested modifications done in group II of this study.

The simplified tray-resin splinting technique may be used clinically when making multiimplant impression procedures as it is expected to minimize chair-side time. Additionally, the simplified technique overcame the drawbacks of the conventional technique without jeopardizing the clinical accepted misfit values. There were limitations for the simplified tray-resin technique of group II. First, the amount of splinting material used was more in amount if compared to the thin sections used to unite the sectioned resin bar. According to Gibbs et al, a direct relation is present between polymerization shrinkage of the used resin and the mass of the splinting material[15]. Based on this, group II technique is more likely to induce higher polymerization shrinkage in the splinting material resulting in higher deviation values on the implant platform level. However, this could be overcome by using a more stable alternative splinting material.

Second, impression copings parallelism would affect seating of the tray as the tray openings are expected to travel at least half the length of the copings to reveal enough space for splints. If impression copings are diverging, tray openings will become larger to facilitate seating of the tray. This means more splinting material will be used to splint the copings to the tray suggesting higher deviation values. Therefore, more investigations are needed to assess the clinical outcomes of this technique.

CONCLUSIONS

Based on the findings of this study, it could be concluded that the conventional resin-on-floss technique showed overall less deviation values when compared to the simplified tray-resin technique for making muliimplant impression. However, values of both techniques remained under the limit of the accepted misfit values proposed in literature suggesting that the simplified splinting technique may be used clinically when making multiimplant impression procedures.

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