Original Article

The Accuracy of Four Impression-making Techniques in Angulated Implants Based on Vertical Gap

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KEY WORDS
Dental Implants;
Impression techniques, Dental;
Dental Implants;
Dental Abutments;
Dental Prosthesis;

ABSTRACT

Statement of the Problem: Precision of the impression taken from implant positions significantly determines accurate fit of implant-supported prostheses. An imprecise impression may produce prosthesis misfit.

Purpose: This study aimed to evaluate the accuracy of four impression-making techniques for angulated implants by stereomicroscope through measuring the vertical marginal gaps between the cemented metal framework and the implant analog.

Materials and Method: A definitive cast with two 15° mesially angulated implants served as the standard reference for making all the impressions and later for accuracy evaluation. Four groups of five samples were evaluated: (1) closed-tray snap-fit transfer, (2) open-tray nonsplinted impression coping, (3) metal splinted impression coping, and (4) fabricated acrylic resin transfer cap. A gold-palladium framework was fabricated over the angulated implant abutments, the fit of which was used as reference. The gaps between the metal framework and the implant analogs were measured in sample groups. Corresponding means for each technique and the definitive cast were compared by using ANOVA and post hoc tests.

Results: The mean marginal gap was 38.16±0µm in definitive cast, 89±19.74µm in group 1, 78.66±20.63µm in group 2, 54.16±24.29µm in group 3, and 55.83± 18.30µm in group 4. ANOVA revealed significant differences between the definitive cast and groups 1 and 2, but not with groups 3 and 4 ($p < 0.05$).

Conclusion: Vertical gap measurements showed that metal splinted impression coping and fabricated acrylic resin transfer cap techniques produced quite more accurate impressions than closed-tray snap-fit transfer and open-tray nonsplinted impression coping techniques do. The fabricated acrylic resin transfer cap technique seems to be a reliable impression-making method.

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Introduction

Precise impression of the implant position is highly essential in fabricating accurately fitted implant-supported prostheses. [1] Hence, an accurate impression-making technique is the first step to obtain the desired multi-implant framework passivity. [2] The accuracy of the definitive cast depends on numerous clinical and laboratory variables intrinsic to the restorative treatment such as the type of impression and cast pouring. [3-4]

An inaccurate impression may cause laboratory difficulties, followed by the prosthesis misfit. The mechanical complications that might be encountered by prosthesis misfit include screw loosening, screw fracture, and occlusal imprecision. [5-6] Therefore, if a multi-implant framework does not attain passivity in its primary casting, the cast structure should be sectioned and an intraoral soldering index should be provided; which requires additional time and imposes cost. [7] Precise fit of a fixed implant-supported restorative device depends on the accuracy of the implant analogs location within the definitive cast. [8]

Various researchers claimed achieving greater accuracy and improved fit with open-tray impression copings; [9-12] whereas; others reported the closed-tray impression methods to be more effective. [13-14] The closed-tray impression technique is considered suitable for a parallel or divergent dual-implant situation. [13]

The closed-tray technique can create discrepancies in the axial rotation and inclination of the analogs; thus, a number of authors have certified the superiority of the open-tray method. [7, 13-15]

The open-tray technique allows the impression coping material to remain in the impression. However, the negative points with this method include having extra parts to control when fastening, some rotational movement of the impression coping when securing the implant analog, and the blind attachment of the implant analog to the impression coping, all of which may result in a misfit of components. [10]

The open-tray technique may use either splinted or nonsplinted implant impression copings. Others have used the splinted technique with minor modifications. [8, 16] It is preferred to non-splinted technique. [16-17] The splinting of the impression copings prevents their rotational movement within the impression material during analog fastening, which ultimately provides better results compared with not splinting. [18-20]

Despite the fact that many authors have compared the open- and closed-tray impression methods, [13, 20] the findings are still contradictory. Most of the research heretofore focused on techniques to improve the accuracy with parallel implants. [15, 20] However, the implants located in close vicinity or with adverse angulations can change the impression-making procedure to a difficult task. Convergent implants placed too close produce several problems, beginning with the impression. These situations are perplexing for restorative dentists since they should overcome certain technical difficulties when making impression from dental implants. [21]

Two studies reported less accurate impressions from angulated implants than with straight implants using an experimental cast containing four or five implants. [9, 18] In contrast, two earlier studies that used two or three implants reported that the angulation had no effect on the accuracy of impressions. [22]

This study describes a method to overcome the difficulties associated with the impression-making techniques for implants placed in close proximity or those having adverse angulations, which makes the placement of the impression copings quite challenging. Moreover, it evaluates a new impression-making method for implants with internal connection. It measures the vertical discrepancy of the reference framework to the analogs within the working cast with the aid of a stereomicroscope to evaluate the four different impression-making techniques described herein.

Materials and Method

A mandibular definitive cast was made of autopolymerizing acrylic resin (Unifast Trad; GC Corporation, Tokyo, Japan). Two 4.1×12mm internal connection ITI implants (Bone Level Implant; Straumann AG, Basel, Switzerland) were used for the impression and measurement comparisons in the approximate region corresponding to the mandibular canine teeth. Each had 20 mm of separation as measured from the center of each implant, as well as a 15° mesial angulation. (Figure 1)

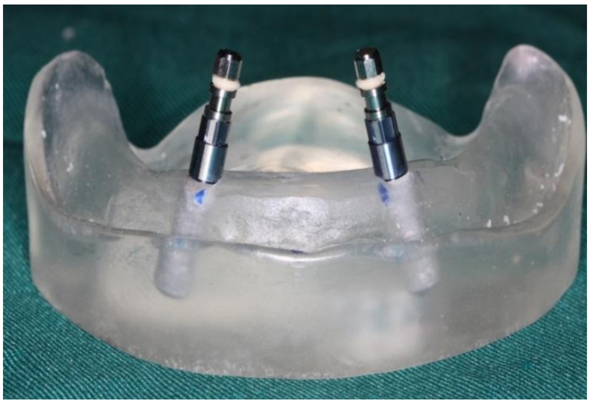

Figure 1: Insertion of each implant at a 15-degree angle in the definitive cast

Two pre-machined 15°-angled titanium abutments

(RC Anatomic Abutment; angled 15°, Straumann AG, Basel, Switzerland) were attached to the implants to compensate for the effects of implant angulation and to make the two abutments parallel. (Figure 2)

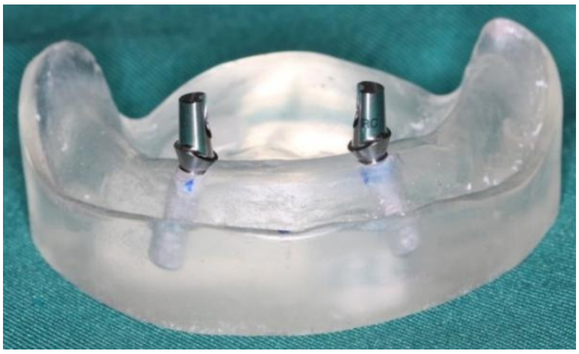

Figure 2: Angled abutments were placed within the definitive cast and then screwed to implants.

Two acrylic resin copings (Pattern Resin; GC Corporation, Tokyo, Japan) were first fabricated on the abutments and were subsequently splinted with a plastic sheet of 2 mm in diameter and then cast with a gold-palladium alloy (Degobond 4; Degussa, Germany) to provide a reference framework. The corresponding abutment screws provided the connection between the abutments and implants. (Figure 3)

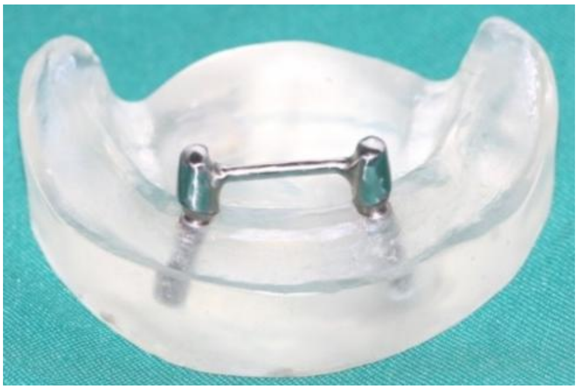

Figure 3: Metal framework served as a reference bar to determine vertical gaps.

The implants were, secured to the acrylic cast with an epoxy resin adhesive (RS Components; Corby, England). The reference bar was placed over the abutments. The framework was removed from the master cast only after polymerization of the epoxy resin was complete. [11] Thus, any discrepancy that could have been caused by the casting procedure was eliminated and a definitive cast with a passively fitting framework was produced. This reference bar was used to verify the accuracy of casts that had been produced from various impressions. To assess the accuracy of the produced casts, the vertical-fit discrepancy of this reference framework was measured as it related to the abutments when placed passively onto the working cast with the aid of a stereomicroscope (Leica Microsystems; Wetzlar, Germany). [17]

For impression tray design, an impression of the definitive cast was made to which two impression copings were attached with an irreversible hydrocolloid (Tropicalgin; Zermack SpA, Badia, Italy). The impression was poured with type IV dental stone (Elite Master; Zermack SpA, Badia Italy). Two tissue stops were placed into a 1-mm thick wax sheet (Modeling Wax; Dentsply Ltd., Weighbridge, UK) that were then placed over the residual ridge, posterior to the impression copings that were blocked out with a 3-mm wax layer. A third tissue stop was incorporated between the implants.

Three location marks (buccal, distal and lingual) were made and included in the impression trays to standardize tray positioning during impression making. An individual autopolymerizing acrylic resin tray (Unifast Trad; GC Corporation, Tokyo, Japan) was initially made from this cast and then cast with a cobalt-chrome (Co-Cr) alloy. The cast tray was 2-mm thick with two openings on top of the tray to allow fastening and unfastening the impression coping screws when using any direct impression-making technique. In addition, various bolts and nuts were employed to allow generic one-eighth inch screws to be used to fasten the tray to the top part of a custom-fabricated impression-making jig. [23]

The definitive cast was fixed with three screws to the stainless steel base of this jig to prevent cast movement during impression making. The impression-making tray was slid in a vertical direction along four custom-fabricated parallel guiding steel pins (11mm in diameter) affixed to the base. This jig provided a single insertion and removal axis that could move in a defined path at the time of the seating and rising phase and provided the exact same condition for all impression-making situations. (Figure 4) [23]

The fitting surfaces of all components were cleaned with isopropyl alcohol before making each impression. [24] The impression copings were first attached to the definitive cast and all open- and closed-tray impression copings were, then, adapted to the impl-

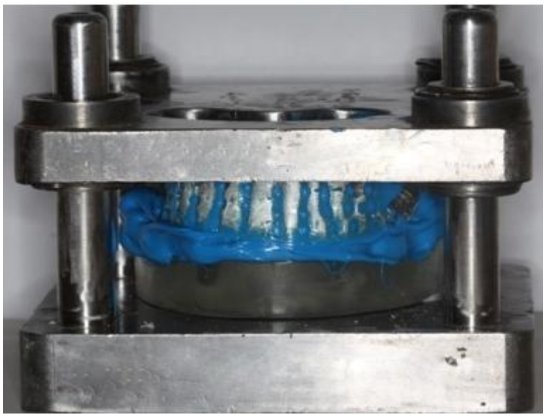

Figure 4: The impression jig used to take impressions

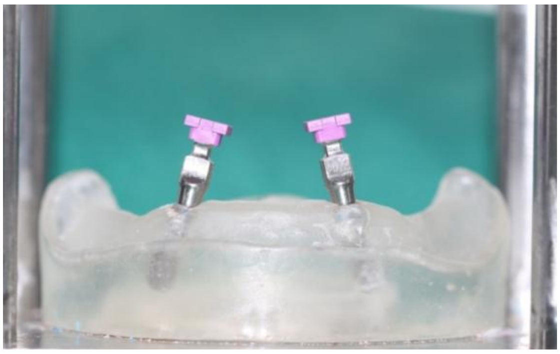

Figure 5: Group 1 closed-tray transfer snap-fit technique model

ants on the master cast to engage the hex**.** Correct seating of the impression post was verified by a prosthodontist with 30 years of professional experience, who made a continuous visual and tactile inspection of the placement of the coping throughout the impression-making and pouring procedures. Four groups of five casts each were used to evaluate the following impression-making techniques:

Group 1: Closed-tray transfer snap-fit

Two closed tray impression copings with snaps were fastened to the two implants in the definitive cast to engage the hex using 15 N/cm of torque. [25] **(**Figure 5)

Group 2: Open-tray nonsplinted impression post

Two square open-tray impression copings were used to transfer the angulated position of the implant. These two open-tray impression copings were fastened onto the two implants in the definitive cast to engage the hex using 15 N/cm of torque. [25] (Figure 6)

Group 3: Metal splinted impression post

Straight metal (Co-Cr) rods, 2.35mm in diameter, affixed with small amounts of acrylic resin (Pattern resin GC Corporation; Tokyo, Japan), were used to attach two

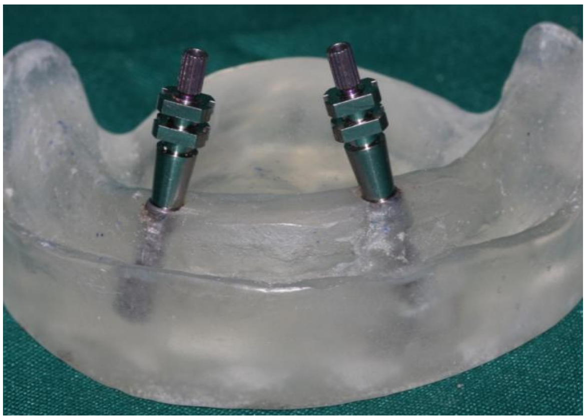

Figure 6: Group 2 open-tray non-splinted impression coping technique model

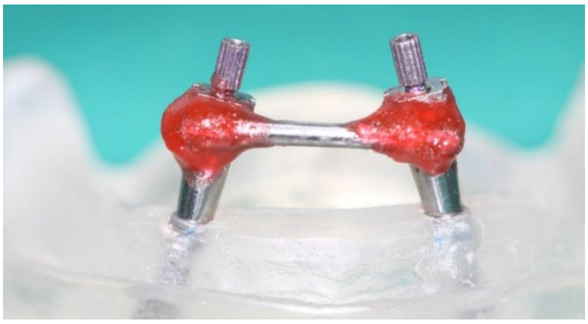

Figure 7: Group 3 metal splint impression coping technique model

square impression copings to each other in an open tray at the level of the circumferential groove to ensure security. [17] (Figure 7)

Group 4: Custom-made acrylic resin transfer cap

Two custom-made acrylic resin transfer caps were made of Pattern acrylic resin (GC Corporation; Tokyo, Japan). They were placed over two angled titanium abutments (RC Anatomic Abutment; angled at 15°; Straumann AG, Basel, Switzerland) (similar transfer caps technique). [26] Finally, during the impression making process were seated on each angulated abutment that had been placed on the two implants in the definitive cast to engage the hex by using 15N/cm of torque. (Figure 8)

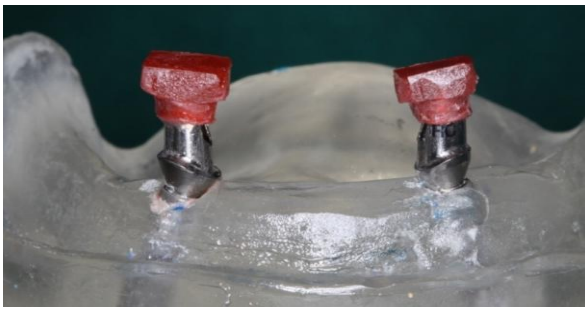

Figure 8: Group 4, custom-made acrylic resin transfer cap technique

In liberator, for making custom-made acrylic resin transfer cap after attachment of abutment to implant analog, the screw access hole was filled by light body impression material (Panasil; Kettenbach, Germany) to prevent penetration of acrylic impression material into it. The abutment was lubricated by Vaseline. The cap was made by pattern acrylic resin (GC Corporation; Tokyo, Japan) by using brush technique. Having polymerized the first layer, more resin layers were added to the cap surface to form square and retentive forms, so that it would be easily picked up after impression- making procedure. The end point of cap was marked by taper carbide bur 699 (ELA; Germany) to check reseating of cap. During impression making, the abutment was detached from the implant and put in impression in line with the marking sign.

Impression making material

The impression materials were left at workroom temperature for one hour in the working environment prior to mixing. [23] The custom tray was covered with VPS adhesive (Reto; Kettenbach, Germany) and left to dry for 15 minutes. Additional monophase silicone impression making material (Monopren Transfer; Kettenbach, Germany) was mixed with a manual gun dispenser (Applyfix 4; Kettenbach, Germany). At the impression making time of each group of samples, this material was injected around group 1 and 2 impression copings, group 3 metal-splinted copings, and group 4 custom-made acrylic resin caps as needed. The loaded tray was placed on the guiding pins of the impression jig and, using hand pressure, slid down onto the definitive cast until it contacted the tissue stops on the master cast. The tray with the impression material was left undisturbed for 10 minutes on the definitive cast to polymerize.

The manufacturer-recommended setting time was doubled to compensate for the delayed polymerization reaction at room rather than at mouth temperature. [24, 26] A 1.25-kg force was exerted over the tray by the weight of the upper jaw of the jig during the impression procedures. (Figure 4) This pressure was enough to force the excess material to flow outward and it was maintained throughout the working time until the polymerization process completed. [11, 18]

In the group with closed-tray technique, the impression copings remained on the definitive cast until complete polymerization of the impression material and removal of the tray. These impression copings were removed from the definitive cast one at a time and attached to the implant analog. The custom-assembled impression coping analog unit was inserted into the impression by firmly pushing it downward into place to its full depth, and then slightly rotating the unit clockwise to feel for the anti-rotational resistance. This tactile test confirmed that the grooves on the coping were properly engaged and locked into place besides that the implant position was accurate. [27]

In groups with open-tray and metal splinted method, the impression copings were unscrewed and the tray was separated from the definitive cast. The implant analogs were then attached and tightened to the impression copings by hand.

In the group 4 wherein the cap was made from an angulated abutment just as in those wherein the closed-tray method was used, the impression coping was fastened to the analog unit and pressed into the impression.

A two-time pouring technique was employed to minimize any setting expansion of the dental stone. Two pieces of latex tubing, each 23×4×8 mm (length × internal diameter × external diameter), were used. [11, 17] The tubes were fitted onto the analogs and poured with die stone (Elite Master; Zermack SpA, Badia, Italy) two hours after the impressions were made by using a ratio of 21 ml of water to 100 g of stone powder. [11, 17]

After the initial setting phase of approximately 10 minutes, the latex tubes were removed. (Figure 9)

Figure 9: Latex tubes removed from implant analogs

A ratio of 2.5 ml of water to 10 g of die stone powder was mixed following the previously described process, injected by using a 20-ml Plastipak syringe (Soha; Karaj, Iran) around the analogs, and was allowed to set for two hours before separation from the impressi-

Table 1: One-way ANOVA used to compare the four techniques (P<0.05 statistically significant)

Technique Study Groups*	N	Mean	SD	F	*p* Value
Closed-tray transfer snap fit (1)	5	89	19.74		
Open-tray non-splinted impression coping (2)	5	78.66	20.63		
Metal splint impression coping(3)	5	54.16	24.29	8.84	$p < 0.0001$
Custom-made acrylic transfer cap (4)	5	55.83	18.30		
Definitive cast	1	38.16	0		

* Group numbers in parenthesis, N=Number, SD=Standard Deviation

Figure 10: The casts trimmed for measuring

Figure 11: Image of the distal abutment-framework interface gap (100× magnification)

ons. [14] The 20 casts comprising the four technique study groups were stored at room temperature for a minimum of two weeks before measurement. [24]

Each cast was then trimmed and marked with a specifically designated number. (Figure 10) All casts were prepared by the same prosthodontist.

For the concentricity measurements, two angulated abutments (RC Anatomic Abutment; angled at 15°, Straumann AG, Basel, Switzerland) were connected to the implants on each cast and two titanium screws were tightened on the right and left analogs at 15 N/cm torque in the same position. As described previously, it was done by using a torque driver to ensure visually that the angulated abutments were parallel. The standard framework was seated on the abutments and the abutment-framework interface gaps were measured on various analogs. Before measuring procedure, the metal framework was cemented on the abutments with Temp Bond Clear (Kerr Corporation; Orange, USA). A clamp was used to maintain the constant seating pressure of 25 N/cm for 5.5 min. [28]

The bar fit accuracy was then quantified by measuring the vertical gaps between the copings and the sample implant analogs by using a stereomicroscope (Leica Microsystems; Wetzlar, Germany) (Figure 11) at three points on each right and left analog at ×100 magnification. [28] The same measurement protocol was used for all cast throughout the study. The subsequent measurements performed on the casts were made by the same prosthodontist. Three demarcations (buccal, distal and lingual) were made on each framework to have standardized measurements within identical framework area in each cast.

The mean of these three measurements determined the size of the gaps in the right or left framework. The mean gap value for each group was calculated based on the average of five consecutive measurements (10 gap values). Various comparisons of the gap dimensions were performed via one-way ANOVA and a post-hoc value of $p< 0.05$ was considered statistically significant.

Results

In our results, the mean fit accuracy was measured by vertical gap measurements in casts representing four impression making techniques. A total of 20 casts were fabricated in four groups (n=5). Approximately 120 gap values were calculated. The results are presented in Tables 1 and 2.The mean values of the master cast were significantly different from those of groups 1 and 2, but not from groups 3 and 4 (Table 2). In addition, the comparison of internal groups showed a statistically signific-

Table 2: Post hoc one-sample t-test used to compare the study groups (μm) with the definitive cast (P<0.05 statistically significant)

Technique Study Groups*	N	Mean	SD	t	*p* Value
Closed-tray transfer snap fit (1)	5	89	19.74	7.24	*p*= 0.002
Definitive cast	1	38.16	0		
Open-tray non-splinted impression post (2)	5	78.66	20.63	5.81	*p*= 0.004
Definitive cast	1	38.16	0		
Metal splint impression post (3)	5	54.16	24.29	2.68	*p*= 0.95
Definitive cast	1	38.16	0		
Custom-made acrylic transfer cap (4)	5	55.83	18.30	3.76	*p*= 0.62
Definitive cast	1	38.16	0		

* Group number shown parenthetically, N=Number, SD=Standard Deviation

ant difference between groups 1 and 4, as well as between groups 2 and 4 ($p \leq 0.001$). Statistically significant differences were also observed between groups 1, 2 and 3 ($p < 0.05$). However, the difference between groups 3 and 4 was not statistically significant.

Discussion

The relationship of a prosthetic superstructure to its underlying implant abutments is considered as the passive fit. Yet, no precise definition or describing parameters for passive fit have been established as a passive fit. The first stage in achieving an accurate, passively fitting prosthesis is to reproduce the intraoral relationship of the implants with the use of impressions. [8] However, a perfect fit is obtained when all the matching surfaces of the implant and prosthesis are contacted with each other without exerting any forces. [8]

In this study, a gap of 38.16 μm was still observed between the framework and the abutment analogs. However, the master cast was produced by using a metal framework. Four techniques as previously named were used to compare the accuracy of impression by measuring the vertical gaps and showed no significant difference between groups 1and 2 in agreement with several authors. [29-30] However, there were greater gaps seen in these groups.

In this study, making impressions via group 2 did not show any statistically significant difference in comparison with group 1 from a precision point of view, which is in contrast with previous studies. [7, 13, 15] This could be due to the 30°-angulation of the implants with one another in this study in which these two techniques, i.e. group 1 and group 2 caused lower precision of the impression in comparison with the two other group 3 and group 4. However, this finding concurred with the results of Carr's investigation [29] in which no statistically significant difference was observed between these two techniques.

In the present study, gap reduction was observed in samples of group 3, indicating the superiority of this method over other techniques. It showed that splinting significantly increased the precision of impression making as demonstrated by previously conducted aforementioned study in which the implants were 30° angulated. [18-20] Similarly, the current investigation found that splinting increased the precision where the implants were angulated toward each other.

Lee *et al*. [31] found that open-tray nonsplinted impression coping and closed-tray transfer coping techniques had similar accuracy for making impressions of three or fewer implants. However, in this investigation where two implants were at 30° angle with each other, the group 3 open-tray metal splinted impression coping was significantly superior and was quite more precise than group 2.

Findings of this study indicated that making an accurate impression through the method used in group 3 definitely depended on the type of splint used, a result, which was in agreement with previously published investigative reports. [18-19] This difference in results could be due to the angulation of implants (30°) used in the present study. However, this finding was also in conflict with various other investigations. [13-15]

Earlier studies showed that a more accurate working cast could be obtained by using the metal-splinted impression copings technique. [17] It confirms that the accuracy of group 3 and 4 was similar, and that both of these methods produce more accurate impressions than those by group 1 and 2.

The current study noted that the angles of implants were compensated for through utilizing angulated abutments. The impressions in the group 4, similar to those of group 3, were significantly more accurate than group 2 and 1. It indicated that this technique was accompanied with the least distortion of impression- making material and, therefore, offered higher accuracy.

These were in line with previous findings about the snap-fit technique. [24, 32-33] It explained the similarity of the plastic impression caps used in the nonsplinted impression-making methods and the acrylic resin splint impression technique for transferring the position of multiple intraoral implants to a laboratory definitive cast. [24]

Choi *et al*. [22] explained that an implant angulation of $\leq 8^{o}$ was the maximum divergence that permitted easy removal of the splinted or nonsplinted impression copings. There is negative relationship between the implant angulation and impression accuracy. [12, 34]

In this study, by having an implant angulation higher than 8° (30° in our case), the impression accuracy could be improved and vertical fit discrepancies were prevented in any impression-making technique. The group 4 custom-made acrylic resin transfer caps were placed over the abutments. The accuracy of this method was similar to metal splinted technique described earlier by Del'Acqua *et al*.; [17] however, they achieved different results when using the splinting custom-made acrylic resin transfer caps with acrylic resin.

Conclusion

Within the limitation of this *in vitro* study, it may be concluded that the rigid metal-splinted impression coping and the custom-made acrylic resin transfer cap techniques produce significantly more accurate impressions than the snap-fit transfer coping and the non-splinted pick-up method. It suggests that custom-made acrylic resin (indirect) transfer cap technique might be a reliable impression- making method in angulated implant position.

Conflict of Interest

None declared.

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