AMERICAN COLLEGE OF PROSTHODONTISTS
Your smile. Our specialty.

Evaluation of the Accuracy of Conventional and Digital Impression Techniques for Implant Restorations

Renata Vasconcellos Moura, DDS, MSc,[1] Alberto Noriyuki Kojima, DDS, MSc, PhD,[2] Cintia Helena Coury Saraceni, DDS, MSc, PhD,[1] Lucas Bassolli, DDS, MSc, PhD,[3] Ivan Balducci, DDS, MSc, PhD,[4] Mutlu Özcan, DDS, Dr Med Dent, PhD,[5] & Alfredo Mikail Melo Mesquita, DDS, PhD[1]

[1]Department of Prosthodontics, Universidade Paulista, São Paulo, Brazil
[2]Department of Dental Materials and Prosthodontics, UNESP SJC, São José dos Campos, Brazil
[3]Department of Cardiovascular and Thoracic Surgery, Universidade de São Paulo, Brazil
[4]Department of Social Dentistry, São Paulo State University, São José dos Campos, Brazil
[5]University of Zurich, Dental Materials Unit, Center for Dental Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Zurich, Switzerland

Keywords
Angulated implants; CAD; dental impression.

Correspondence
Renata Vasconcellos Moura, Universidade Paulista - Post Graduation, Rua Doutor Bacelar 1212, São Paulo, São Paulo 04026-002, Brazil.
E-mail: renata_vmoura@hotmail.com

The authors deny any conflicts of interest related to this study.

Accepted February 17, 2018

doi: 10.1111/jopr.12799

Abstract

Purpose: The increased use of CAD systems can generate doubt about the accuracy of digital impressions for angulated implants. The aim of this study was to evaluate the accuracy of different impression techniques, two conventional and one digital, for implants with and without angulation.
Materials and Methods: We used a polyurethane cast that simulates the human maxilla according to ASTM F1839, and 6 tapered implants were installed with external hexagonal connections to simulate tooth positions 17, 15, 12, 23, 25, and 27. Implants 17 and 23 were placed with 15° of mesial angulation and distal angulation, respectively. Mini cone abutments were installed on these implants with a metal strap 1 mm in height. Conventional and digital impression procedures were performed on the maxillary master cast, and the implants were separated into 6 groups based on the technique used and measurement type: G1 – control, G2 – digital impression, G3 – conventional impression with an open tray, G4 – conventional impression with a closed tray, G5 – conventional impression with an open tray and a digital impression, and G6 – conventional impression with a closed tray and a digital impression. A statistical analysis was performed using two-way repeated measures ANOVA to compare the groups, and a Kruskal-Wallis test was conducted to analyze the accuracy of the techniques.
Results: No significant difference in the accuracy of the techniques was observed between the groups. Therefore, no differences were found among the conventional impression and the combination of conventional and digital impressions, and the angulation of the implants did not affect the accuracy of the techniques.
Conclusions: All of the techniques exhibited trueness and had acceptable precision. The variation of the angle of the implants did not affect the accuracy of the techniques.

The passive fit of an implant-supported prosthesis depends on several factors, including the accuracy of the impression technique and the resulting master cast produced.[1,2] The implant-abutment connection is directly related to the long-term success of the prosthesis. An improper connection can increase biological problems and cause mechanical issues such as occlusal problems and screw loss from the abutment or implant. Therefore, an accurate impression is extremely important to produce a reliable cast.[2-7]

Accuracy consists of precision and trueness (ISO 5725-1).[8-10] Precision represents the degree of reproducibility between repeated measurements. As the precision increases, the predictability of the measurement increases. Trueness describes the closeness to the actual dimensions of the object, which is defined by a comparison between the measurement control and a test object.[1,8,9]

The accuracy of gypsum cast fabrication for implant transfer positioning of a prosthesis is influenced by the impression technique, parallelism or non-parallelism of implants, depth of the implant position, type of impression material used, dimensional stability of the gypsum, and the repositioning of copings in the correct position.[4-6,9] The angulation of the implants may

Table 1 Materials required for the study

Material	Manufacturer	Quantity
Polyurethane maxilla cast	Nacional Ossos, Jaú, Brazil	1
External hexagonal implant (3.75 × 11 mm)	Implacil de Bortoli, Sao Paulo, Brazil	6
Implant engine	Smart Driller, Carapicuíba, Brazil	1
Counter-angle – reducer 20:1	Anthogyr; Sallanches, France	1
Manual torque wrench	Implacil de Bortoli, Sao Paulo, Brazil	1
Mini conical abutments (1.0 mm metal strap)	Implacil de Bortoli, Sao Paulo, Brazil	6
Bench Scanner 3 series (optical system)	Straumann- Dental Wings, Basel, Switzerland	1
Carborundum disc	Dentorium – Labordental, Sao Paulo, Brazil	1
Scan body	Neodent, Straumann, Basel, Switzerland	1
Plastic autoclavable perforated tray	Angelus, Londrina, Brazil	2
Tungsten maxicut drill PM n^0 1251	American Burrs, Pedra Branca, Brazil	1
Open tray transfer	Implacil de Bortoli, Sao Paulo, Brazil	6
Closed tray transfer	Implacil de Bortoli, Sao Paulo, Brazil	6
Mini conical analog	Implacil de Bortoli, Sao Paulo, Brazil	60
G.C. Pattern resin	GC Dental, Tokyo, Japan	1
Vinylpolysiloxane Futura AD	Nova DFL, Rio de Janeiro, Brazil	1
Special type-IV gypsum	Fujirock, GC, Tokyo, Japan	1
Digital caliper	Mitutoyo, Tokyo, Japan	1

increase the likelihood of the impression material becoming dislodged and the subsequent distortion of the definitive cast. Each step of the impression procedure can be influenced by human error or impression material error.[11]

To date, several implant impression techniques, such as the open tray and closed tray, and different impression transfers and materials have been investigated regarding their accuracy.[1-9]

Implant impressions can be classified as direct or indirect techniques. Direct techniques are also described as open tray impression techniques because the tray has an open window for unscrewing the guide pins of the impression copings.[1,3,12] During impression removal, the whole set is removed at the same time, and the copings are repositioned by fixation of this same screw.

Indirect techniques are also known as closed tray impression techniques. These techniques consist of transfers that remain on the implants while the impression tray is removed from the mouth. The transfer is removed from the implant, attached to the analog outside the mouth, and repositioned onto the impression. The closed tray technique is performed when indications such as limited space between interarches, nausea, or difficulty in accessing a posterior implant are present.[12,13]

The accuracy of conventional impression techniques depends on the impression material, tray type, and the technique used.[11] Fabrication of a virtual cast can be performed intraorally or through the digitalization of conventional casts with a scanner. Bench scanners are becoming more frequently used because they combine the advantages of a CAD/CAM prosthesis and decreased laboratory cost; therefore, digital impression techniques at the implant level play an important role in the development of a fully digital workflow for implant restorations.[14,15] CAD/CAM-fabricated restorations with indirect data capturing require precise casts, making precise impressions indispensable, and this technology increases the potential for the implant-supported prosthesis to have a better passive fit, which is considered an essential prerequisite for maintaining osseointegration.[1,9]

In some cases, parallel installation of the implants is impossible, and it is necessary to angle them during surgery.[2] The effect of angulation on the accuracy of casts has been investigated, but some studies have shown that an angle of less than 30° does not affect cast accuracy.[1,5]

The aim of this in vitro study is to compare the precision and accuracy of conventional (open and closed tray) technique with a combination of conventional and digital techniques and to evaluate the accuracy of implant positions at the implant platform level in the presence of angulated implants on these techniques.

Materials and methods

The materials used in this study are detailed in Table 1.

Polyurethane cast and implant installation

A polyurethane maxilla cast, which simulates the human maxilla bone according to the standards of ASTM F1839 (the standard specification for rigid polyurethane foam for use as a standard material for testing dental and orthopedic devices), was used. Cutouts in the maxilla were made using an arc of a saw frame to delimit the area of interest for research.

Six self-screw implants were installed in this cast at the bone level, following surgical protocol and asepsis care, with conical-type and external hexagonal-type connections (3.75 mm diameter, 11 mm length). The implants were inserted into the polyurethane cast using surgical drills with diameters of 2.0, 2.8, and 3.2 mm at a velocity of 800 rpm. An implant engine was used, and a 20:1 counter-angle reducer and a protractor were used to aid implant angulation.

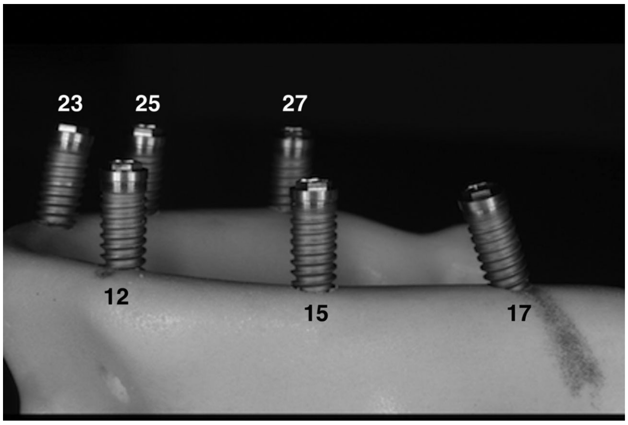

Figure 1 Lateral view of the implants and angulations.

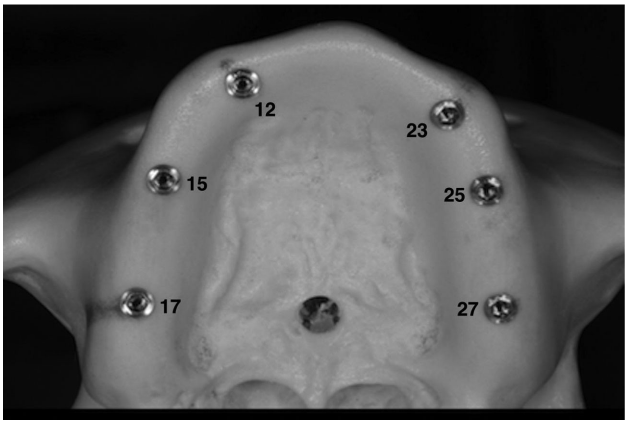

Figure 2 Occlusal view of the implants (17, 15, 12, 23, 25, and 27).

The implants were placed in the following areas and with the following angulations: (1) implant 17 (maxillary right second molar): 15° mesial angulation; (2) implant 15 (maxillary right second premolar): 0° angulation; (3) implant 12 (maxillary right lateral incisor): 0° angulation; (4) implant 23 (maxillary left canine): 15° distal angulation; (5) implant 25 (maxillary left second premolar): 0° angulation; and (6) implant 27 (maxillary left second molar): 0° angulation. Implants 17 and 23 were angled to allow evaluation of material dislodgement between implants with an opposed disposal and angulation when possible (Figs 1 and 2).

Mini conical abutments with a 1 mm metal strap were installed on all of the implants using a manual torque wrench until a torque of 20 Ncm was reached, as recommended by the manufacturer. The master cast was marked in low relief with a carborundum disc, which served as guidance for the measurements to be made at exactly the point of each abutment.

Groups

In this study, the polyurethane maxilla served as a master template for each impression technique performed. For standardization of the impressions, a single operator performed all techniques. Each group consisted of five impressions, resulting in a total of 25 casts per group. To minimize any human errors or statistical failures of the measurements, element 17 was used as a fixed point, and then, the sequence was followed until element 27 was performed (Table 2). The sequence included the master cast, and the implant measurements were performed five times directly on the maxilla.

Impression techniques

Digitalization was performed using a bench scanner, and the master cast was placed directly on the tablet with the scan body installed on the implants (Fig 3). For the open tray conventional impression, a plastic autoclavable perforated tray was used; it was adapted for the impression by removing the occlusal part of the tray using a tungsten maxicut drill and leaving the outer parts and the center of the tray. Six open tray transfers were installed on the mini conical abutments of the master cast, each with a torque of 10 N/cm on the clamping screw. These transfers were splinted using dental floss and a Marta fur brush, and small increments of chemically polymerizable acrylic resin were deposited onto the dental floss by dipping the brush into the monomer and then the polymer (Nealon technique), thus ensuring fixation and preventing the movement of these structures during the impression. This resin structure was cut with a carborundum disc, and a new union was made after 17 minutes by repeating the same procedure.

A plastic perforated autoclavable tray was used for the closed tray conventional technique. Six closed tray transfers were installed on the master cast mini abutments. After the impression was obtained, these were removed from the implants, fixed to the analog using the same implant connection, and introduced into the impression.

Vinylpolysiloxane (VPS) impression material was used for both techniques, following the manufacturer's recommendations. The double-mixing technique was used, in which light and heavy silicones were produced using a tray at the same time the master cast was produced. The setting time of the material was 6 minutes. An analog was installed on each transfer using the same implant connections and without movement of the transfers. After 40 minutes, a special type-IV gypsum was poured over the impression, and after setting, removal was performed to obtain the definitive casts. This sequence of procedures was repeated to obtain five casts for each group.

Measurement procedures

The measurements at G1 (caliper), G3, and G4 were obtained using a digital caliper, and the measurements at G2, G5, and G6 were obtained via the Straumann CAD software system. Measurements were performed starting on the low relief side and proceeding to the mini abutment of implant 17, resulting in the following sequence of measurements (Fig 4): implants 17-15 (a), implants 17-12 (b), implants 17-23 (c), implants 17-25 (d), and implants 17-27 (e). The data for the five measurements were stored in an Excel table (Microsoft Office 365; Microsoft Corp., Redmond, WA), and the average and standard deviation of the measurements were calculated for each group.

Table 2 Groups included in the study, by the technique and method of measurement

Group	Specimen	Cast technique	Method of measurement
G1	Polyurethane maxilla	—	Caliper (Control)
G2	Polyurethane maxilla	Digitalization	Software CAD Design (Dental Wings 3 series)
G3	Gypsum cast	Open tray	Caliper
G4	Gypsum cast	Closed tray	Caliper
G5	Gypsum cast	Open tray + Digitalization	Software CAD Design (Dental Wings 3 series)
G6	Gypsum cast	Closed tray + Digitalization	Software CAD Design (Dental Wings 3 series)

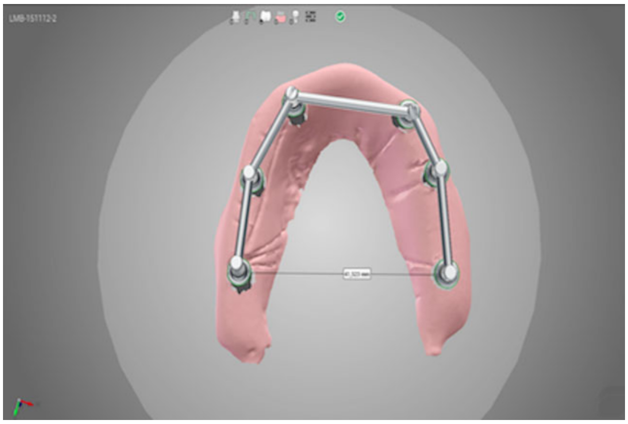

Figure 3 Digitalized view.

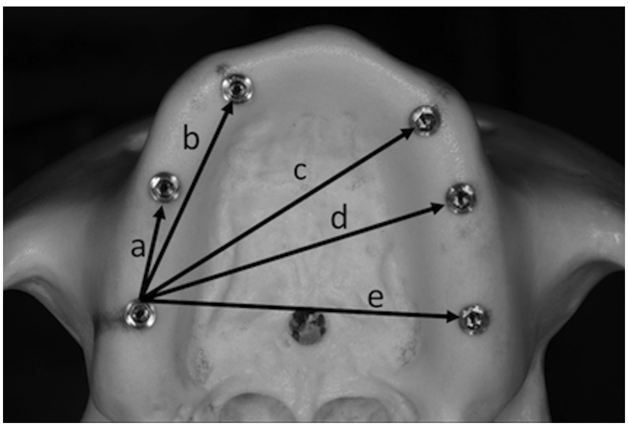

Figure 4 Measurement points between the implants.

Statistical analysis

The mean and standard deviation were calculated for each technique, and the coefficient of variation for each group was calculated to determine the accuracy of the technique. Two-way repeated-measures ANOVA was performed to assess the interaction of and the correlation among the techniques and measurement points. A Kruskal-Wallis test was performed to analyze the accuracy of the techniques.

Comparisons with a type I error probability of less than 5% ($p < 0.05$) were considered statistically significant. The Minitab program was used for the descriptive analysis, while the Statisix 9.1 program was used to perform two-way repeated-measures ANOVA and the Kruskal-Wallis test.

Results

The descriptive statistics are shown in Table 3. The mean and standard deviation for each group and the measurement points are shown. Analysis of the accuracy of the techniques was performed using the coefficients of variation. The descriptive statistics indicated that G2, G5, and G6 had higher coefficients of variation.

The data were submitted to a two-way repeated-measures ANOVA to evaluate differences between the techniques. According to the table, all of the techniques were accurate ($p = 0.1099$), because no differences were found relative to the control group (Table 4). Regarding the angulation of the implants using the different techniques, no statistically significant differences were observed among the measurement points a, b, c, d, and e (Table 4), and indicated by the Kruskal-Wallis test results in Table 5.

Discussion

This study compared conventional techniques alone with combinations of conventional and digital techniques to determine whether these combinations can lead to a significant change in the maxilla. The results showed no significant difference between the use of direct digitization of the cast and the control group (caliper), indicating that the same level of accuracy was achieved with and without the countertop scanner.

Accurate impressions are key to the passive fit of implant-supported prostheses. As a step of utmost importance in this experiment, we chose to focus on techniques with high clinical relevance and to reproduce the procedure as it is performed in the dental office. VPS material was used, which, according to Kurtulmus-Yilmaz et al[2] and Prithviraj et al,[6] shows no significant differences compared with polyether, and this material exhibits the highest accuracy in the presence of angled implants.

According to Cerqueira et al,[12] an important step in the conventional technique using an open tray is the union between the transfer and the acrylic resin. We used the self-curing acrylic resin GC Pattern because one study showed that it exhibits less shrinkage polymerization than the self-curing acrylic resin Duralay. The separation of this structure and formation of a new union between transfers required a setting time of 17 minutes, as recommended by the previous study.

Table 3 The mean (M), standard deviation (SD), and coefficient of variation (CV) of the implants

	a (17–15)		b (17–12)		c (17–23)		d (17–25)		e (17–27)	
	M ± SD	CV (%)	M ± SD	CV (%)	M ± SD	CV (%)	M ± SD	CV (%)	M ± SD	CV (%)
G1	12.59 ± 0.02	0.2	28.29 ± 0.15	0.5	41.26 ± 0.2	0.5	41.17 ± 0.08	0.2	40.35 ± 0.3	0.8
G2	12.29 ± 0.5	4.4	29.08 ± 1.3	4.6	41.90 ± 1.9	4.5	41.80 ± 1.8	4.3	42.25 ± 1.4	3.4
G3	12.57 ± 0.2	1.5	28.37 ± 0.09	0.3	41.20 ± 0.1	0.4	41.27 ± 0.4	1.1	41.47 ± 0.3	1.3
G4	12.54 ± 0.1	1.0	28.41 ± 0.1	0.4	41.48 ± 0.4	0.9	41.53 ± 0.7	1.7	41.51 ± 0.5	1.2
G5	12.39 ± 0.2	1.7	28.57 ± 0.8	3.0	41.60 ± 0.9	2.3	41.29 ± 0.4	1.1	41.11 ± 0.4	1.1
G6	12.05 ± 0.5	4.1	29.20 ± 1.07	3.6	42.02 ± 1.2	2.9	42.44 ± 1.1	2.6	41.96 ± 1.4	3.3

Regarding the precision of the techniques, this study showed no significant differences between the technique groups. Other authors[4,18,20] have also shown that the open- and closed-tray techniques exhibit no significant differences; however, some studies[2,3,17-19] have reported higher accuracy of the open-tray conventional technique. Although our study did not demonstrate a difference between the techniques, accuracy is a highly controversial subject in the literature. This is noted by Spector et al,[20] who verified the accuracy of conventional techniques and found distortion in all of them, but they did not determine which technique was the most accurate.

In this study, the scanning technique showed good results in terms of accuracy, as no significant differences were found between the control group (G1) and the group that used direct scanning of the maxilla (G2) or the groups in which digitization of casts was performed by conventional techniques (G5 and G6). Lee et al[9] found that digital techniques are comparable to conventional techniques and reported a difference in the vertical positioning of the implant in their study; however, in the analysis of all groups, higher coefficients of variation were observed for the scanned groups (G2, G5, and G6, with coefficients of variation of 4.24%, 1.98%, and 3.30%, respectively). G3 and G4 (the conventional groups) had lower coefficients of variation, with an average of less than 1% each. Because the images are 3D, positioning of the CAD Design cursor in exactly the same position on all of the virtual casts obtained was difficult compared to the exact measurement (in mm) of the area between the implants. This difficulty was not reported in other articles, and the group that had a coefficient of variation of 4.24%, although considered a low value, was the group that had the highest percentage of variation.

To verify the accuracy of the implant angle variable, mesially angled measurements were performed for implant 17. In the statistical analysis of measurements in relation to the other angled implant (implant 23), the slope did not affect the accuracy of the impression techniques, as shown by the results of the Kruskal-Wallis test.

Similar to other studies, this study found no difference in the measurements of the distances between angled and straight implants for conventional techniques.[1,13,18] Hazboun et al[18] conducted a study to evaluate the distances between angled and straight implants in impressions made using open and closed trays and found no statistically significant differences between the groups or the angles.

Table 4 Results from two-way repeated-measures ANOVA, which show no significant difference between the impression techniques and the technical-angle interaction; $p > 0.05$

Source	DF	SS	MS	F	*p*
Technique	**5**	**12.2**	**2.44**	**2.03**	**0.1099**
Error T*R		24	28.8	1.20	
T*Angle	**20**	**12.7**	**0.63**	**1.08**	**0.3811**
Error T*R*Angle		96	56.3	0.59	
Total	**149**	**19,937.3**			

The results of this in vitro study show that no statistically significant differences exist between conventional techniques alone and combinations of conventional and digital techniques because no significant differences in parameters relative to the control group were found. These results show the accuracy (precision and veracity) of all techniques despite the higher coefficient of variation of techniques involving scanning; however, another study,[21] in which plaster casts were scanned using a countertop scanner and compared for discrepancy, veracity, and reproducibility, reported that conventional techniques were more accurate than digital techniques.

The statistical analysis indicates the clinical relevance of this study. No significant differences were found between the measurements of the casts obtained and those of the maxilla. This finding shows a high degree of reproducibility relative to the actual measurements of the maxilla. A high coefficient of variation was not found between the conventional techniques alone and the conventional techniques combined with digital techniques, which indicates the accuracy of all of the techniques studied here.

The limitations of this study are that the procedure has not been evaluated under clinical conditions and that the implants did not account for the presence of soft tissue, used only one type of implant connection, and were tested using a single impression material; however, the results still demonstrated the accuracy of the different techniques. With the development of CAD technology, new studies should be performed to evaluate the accuracy of digital and conventional techniques for

Table 5 Comparison between the impression technique and technical-angle interaction (Kruskal-Wallis statistics show no significant differences)

a 17-15	
Kruskal-Wallis statistic	5.9240
p-Value, using the chi-squared approximation	0.3137
b 17-12	
Kruskal-Wallis statistic	1.9996
p-Value, using the chi-squared approximation	0.8492
c 17–23	
Kruskal-Wallis statistic	1.4884
p-Value, using the chi-squared approximation	0.9144
d 17–25	
Kruskal-Wallis statistic	5.0829
p-Value, using the chi-squared approximation	0.4058
e 17–27	
Kruskal-Wallis statistic	10.4333
p-Value, using the chi-squared approximation	0.0638

application in daily dental surgery and to improve the use of these new techniques.

Conclusions

Given the limitations of this study, the results indicate that

1. All of the techniques exhibit trueness.
2. All of the techniques have acceptable precision.
3. The variation of the angle of the implants did not affect the accuracy of the techniques.

References

1. Papaspyridakos P, Gallucci GO, Chen C-J, et al: Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin Oral Implants Res 2016;27:465-472
2. Kurtulmus-Yilmaz S, Ozan O, Ozcelik TB: Digital evaluation of the accuracy of impression techniques and materials in angulated implants. J Dent 2014;42:1551-1559
3. Kim JH, Kim KR, Kim S: Critical appraisal of implant impression accuracies: a systematic review. J Prosthet Dent 2015;114:185-192
4. Ebadian B, Rismanchian M, Dastgheib B, et al: Effect of different impression materials and techniques on the dimensional accuracy of implant definitive casts. Dent Res J 2015;12:136-143
5. Giménez B, Özcan M, Martínez-Rus F, et al: Accuracy of a digital impression system based on parallel confocal laser technology for implants with consideration of operator experience and implant angulation and depth. Int J Oral Maxillofac Implants 2014;29:853-862
6. Prithviraj DR, Pujari ML, Garg P, et al: Accuracy of the implant impression obtained from different impression materials and techniques: review. J Clin Exp Dent 2011;3:106-111
7. Vojdani M, Torabi K, Ansarifard E: Accuracy of different impression materials in parallel and nonparallel implants. Dent Res J 2015;12:315-322
8. Ender A, Mehl A: Accuracy of complete-arch dental impressions: a new method of measuring trueness and precision. J Prosthet Dent 2013;109:121-128
9. Lee SJ, Betensky RA, Gianneschi GE, et al: Accuracy of digital versus conventional implant impressions.Clin Oral Implants Res 2015;26:715-719
10. Guth J-F, Keul C, Stimmelmayr M, et al: Accuracy of digital casts obtained by direct and indirect data capturing. Clin Oral Investig 2013;17:1201-1208
11. Yuzbasioglu E, Kurt H, Turunc R, et al: Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health 2014;14:10
12. Cerqueira NM, Ozcan M, Gonçalves M, et al: A strain gauge analysis of microstrain induced by various splinting methods and acrylic resin types for implant impressions. Int J Oral Maxillofac Implants 2012;27:341-345
13. Conrad HJ, Pesun IJ, DeLong R, et al: Accuracy of two impression techniques with angulated implants. J Prosthet Dent 2007;97:349-356
14. Stimmelmayr M, Beuer F, Edelhoff D, et al: Implant impression techniques for the edentulous jaw: a summary of three studies. J Prosthodont 2014;25:146-150.
15. Nakhaei M, Madani AS, Moraditalab A, et al: Three-dimensional accuracy of different impression techniques of dental implants. Dent Res J 2015;12:431-437
16. Hsu C, Millstein PL, Stein RS: A comparative analysis of the accuracy of implant transfer techniques. J Prosthet Dent 1993;69:588-593
17. Jo SH, Kim KI, Seo JM, et al: Effect of impression coping and implant angulation on the accuracy of implant impressions: an *in vitro* study. J Adv Prosthodont 2010;2:128-133
18. Hazboun GBA, Masri R, Romberg E, et al: Effect of implant angulation and impression technique on impressions of NobelActive implants. J Prosthet Dent 2015;113:425-431
19. Leandro LNR, Junior RBB, Teixeira ML, et al: Different materials and techniques for accurate molding for adaptation in angled implants. Rev Gaúch Odontol 2014;62:149-152
20. Spector MR, Donovan TE, Nicholls JI: An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent 1990;63:444-447
21. Cho SH, Shaefer O, Thompson GA, et al: Comparison of accuracy and reproducibility of casts made by digital and conventional methods. J Prosthet Dent 2015;113:310-315