IJBPAS, October, 2016, 5(10): 3296-3319

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

EFFECT OF DENTAL IMPLANT PLACEMENT ANGULATION AND SPLINTED AND NON-SPLINTED IMPRESSION TECHNIQUES ON THE ACCURACY OF IMPRESSIONS IN TWO 3I AND DIO IMPLANT SYSTEMS

BIJAN HEIDARI, DDS, MS*, SAMAN FALLAHI, DDS, MS, ALIREZA IZADI, DDS, MS***, PEGAH RADAN, DDS# AND SAHAR MUSAVI, DDS, MS##**

* Assistant Professor, Dental implants Research Center, Dept. of Prosthodontics; Dental School, Hamedan University of Medical Science, Hamadan, Iran.

** Assistant Professor, Dept. of Prosthodontics. Islamic Azad University, Tehran, Iran

***Assistant Professor, Dept. of Prosthodontics; Dental School, Hamedan University of Medical Science, Hamadan, Iran.

#postgraduate student, Dept. of Prosthodontics, Dental School, University of Medical Sciences, Hamadan, Iran

Assistant Professor, Dept. of Prosthodontics, Dental Faculty, Ardabil University of Medical Sciences, Ardabil, Iran.

Reprint requests and correspondence to: Sahar Mousavi, DDS, MS, Assistant Professor, Dept. of Prosthodontics, Dental Faculty, Ardabil University of Medical Sciences, Janbazan Sqr, Ardabil, Iran 56189-53141; TEL: +98-4533510054; fax: +98-4533510054; E Mail: dr.smousavi84@gmail.com

ABSTRACT

Background and Aim: No technique has been proven to guarantee a completely passive fit of prosthetic frameworks in implant-supported prostheses up to now. The present study assessed the effect of implant angulation, impression technique and system on the accuracy of implant impressions.

Materials and Methods: In this experimental trial, 2 stainless steel master casts were fabricated. Four 3i and DIO implant analogues were placed on each master model. The dimensions of implants and their angulations on the master model and fabricated casts were compared using coordinate measuring machine. The data were subjected to three-factor analysis of variance and Tukey post-hoc tests.

Results: Different values of impression accuracies were noted regarding implant angulation, implant system, and impression technique. The least distances from the parallel analogue were observed using splinted copings in 3I implant system while angulated analogue showed lower accuracy values.

Conclusion: The most dimensional accuracies were noted in the splinted copings using 3i implant system while impression errors were higher in angulated implants than parallel implants. Although more time-consuming; splinted open tray technique are recommended for clinical impression making in implant restorations.

Keywords: Dimensional accuracy, Impression technique, Implant angulation, Implant system

INTRODUCTION

Dental implants are considered an ideal and successful treatment modality in treatment procedures for complete and partial edentulism, single-tooth replacements and implant-supported overdentures.[1] A passive fitness is necessary between the fixture and the superstructure for the long-term success of these treatments.[2] The term "passive fitness" in implant dentistry indicates a particular type of adaptation in prosthesis, in which the implant body has adequate fit, paving the way for bone remodeling, although it is very difficult to achieve a complete tension-free fit without any errors.[3] An adequate and favorable fit is a state in which the stresses produced are physiologically tolerable and after placement of the prosthetic appliance, the bone–implant complex will not receive any injuries and trauma.

Reconstruction of the intraoral relationships of the implants through impression-making procedures is the first step in manufacturing a precise prosthetic appliance with a complete fit. Precise impression-taking step, as the primary step in fabricating prosthetic appliances, is an important step in this context.[4] Given anatomic limitations and surgical considerations, unparalleled placement of several implants in the clinic is inevitable. Therefore, in implant-supported prosthetic treatments, there is always the problem of unparalleled placement of abutments.[5] In this context, use of angled abutments has been advocated in implant dentistry. Some manufacturers have introduced implants with angles from zero up to 60 degrees and suggested various techniques to cover the angle of implant placement.

Different impression techniques have been suggested for the provision of accurate casts and two principal techniques are used to transfer the position of implants from the oral cavity to a cast: direct (open) and indirect (closed) impression techniques.[5] In the open technique, splinted method is used to increase the accuracy of impression-making technique, in which self-cured acrylic resin or composite resin is used to connect the implants to each other.[6] It appears that splinting the copings to each other with the use of this technique might result in higher stability of copings in the impression material, preventing their movement during tightening of the fixture analog or tightening and loosening of screws. Some researchers have reported a higher accuracy rate with the pick-up open tray technique compared to the closed tray technique.[4,7–9] However, there are some problems with the open technique, including the rotational or vertical movements of copings.[10–12]

Assucao et al evaluated the accuracy of different impression-taking techniques with splinted implants in two different placement angulations (perpendicular to the surface and a deviation of 65º) with the use of polyether impression material and showed lower accuracy in casts produced with the non-splinted technique compared to the splinted technique.12

Choi et al evaluated the accuracy of splinted and non-splinted 2-step impression techniques in the fabrication of implant-supported restorations with internal connections and reported comparable accuracy of the two techniques at 8° divergence.[13]

Absence of parallelism in implants gives rise to an undesirable path, which might distort the impression material during its removal from the oral cavity, producing a distorted master cast, especially with the use of the closed tray technique. When several non-parallel implants are placed with different angles, distortion of the impression material during the removal of the tray might increase. In some studies, impressions with lower accuracy have been reported with the use of angled implants compared to parallel implants and with the use of laboratory casts with 4 or 5 implants.[12,14] However, in two other studies with the use of 2 or 3 implants, it was shown that implant placement angle has no effect on impression accuracy.[13,15]

Assunção et al evaluated the effects of two implant angulations, 90º and 65º, with the use of AutoCAD software program and profilmotry.[16] Based on the results, in implants perpendicular to the horizontal surface (90º), no significant differences were observed in mean values with the use of profilometry and AutoCAD software program. However, with the 65º, there were significant differences between the two groups. Therefore, the accuracy of implant angulation might be different in different techniques or implant angulations.

Masri evaluated the effects of impression technique, connection type and implant placement angulations on the accuracy of impressions taken from implants.[17] Based on the results of the study, there were no significant differences in the accuracy of impressions between the open and closed try impression techniques, except for the fact that the closed tray technique exhibited higher accuracy compared to the open tray technique in relation to the extent of the horizontal plane. M Pikos et al determined the effects of impression technique and implant placement angulations on the accuracy of implant impressions splinted through internal and external connections, with the use of a new laboratory tool.[18] Based on the results, in implants with external connection, the accuracy of impressions was not influenced by the impression technique, the implant angulation or their cumulative effect. However, in implants with internal connection, the accuracy of impressions was affected only by the implant angulation and the highest inaccuracy was shown with 25° implant angulation. Therefore, use of the open or closed tray technique had no effect on the accuracy of impressions from multiple implants and the reciprocal effects of impression technique and implant angulations were not significant. However, in implants with internal attachment, the implant angulation had no significant effect on the accuracy of impressions.

Given the importance of accurate impressions in implant treatment techniques, the results of the use of different impression techniques, such as transitional, pickup and splint techniques, and surface preparation of impression copings and the accuracy of die materials or impression materials such as polyether and polyvinylsiloxane have been evaluated on the accuracy of impressions in various studies. In addition, other relevant factors such as the implant placement angulation, implant length and implant systems have been evaluated in previous studies and different results have been reported. Undoubtedly, it is not possible to place implants in a parallel manner in all the cases and since the effect of implant angulation, impression technique and the implant system on the accuracy of implant impressions have not been evaluated simultaneously, the present in vitro study was undertaken to determine the effect of implant placement angulation, impression technique and implant system on the accuracy of implants.

MATERIALS AND METHODS

The present in vitro study was carried out in the Faculty of Dentistry, Hamadan University of Medical Sciences, Hamadan, Iran, in the 2014–2015 educational year.

The analogues of 3I and DIO implant systems were placed in two stainless steel models parallel to each other or with 15° and 25°angulations; two impression techniques of splinted and non-splinted were used and the samples were evaluated and compared in relation to dimensional changes of the abutments and the accuracy of the transfer of their positions from the models to the casts. The sample size was calculated at 15 samples in each group based on a study by Jo et al[19] (2010), using PS software program by considering $\alpha=0.05$, $\beta=0.2$, difference of 0.06 and standard deviation of 0.091. Simple non-random sampling technique was used.

Two stainless steel models designed by Woks Solid software program in the form of dental arch were used for the purpose of this experimental study. In each of these models, 4 cavities were prepared, measuring 10 mm in length and 4 mm in diameter, 10 mm apart from each other. Cavities 1 and 2 in the anterior part of the models (one on the right and one on the left) were parallel to each other and perpendicular to the plates and cavities 3 and 4 were placed on the right and left sides of the posterior part of the dental arch at 15º and 25º on the model, respectively. In one of these models, 4 analogs of the 3I implant system (Innovations Inc., Barcelona, Spain) were placed in the cavities and fixed in place by cyanoacrylate cement. In the other model, 4 analogs of the DIO implant system (GU Corporation, Bussan, Korea) were placed in the cavities.

First, an initial alginate impression (Kerr, Italia, S,R,L. Corp., Salerno, Italia) was taken from the principal model using the open tray technique with a prefabricated tray (Fig. 2). The impression was poured and an initial cast was achieved. A special tray was made on this cast for the final impression.

To this end, first impression copings were placed on the model and two layers of base plate wax (High stability modeling wax, Dentsply, USA),[31,32,52] with a diameter of 1 mm, were placed around the copings to create the space necessary for the impression copings to create the space necessary for the impression material. The special tray was fabricated with self-curing acrylic resin (Resin Megatreay, Megadenta, Gmbh, Germany) for the final impression (Fig. 3). Then all the tray surfaces were perforated with a round bur in a handpiece to create holes measuring 2 mm in diameter, 10 mm apart from each other. Finally, 60 special trays were fabricated from the models and assigned to 4 groups as follows based on the impression technique and the implant system (n=15):

Group 1: 15 trays for the 3I system with the non-splinted impression technique (NS-3I)

Group 2: 15 trays for the 3I system with the splinted impression technique (S-3I)

Group 3: 15 trays for the DIO system with the non-splinted impression technique (NS-DIO)

Group 4: 15 trays for the DIO system with the splinted impression technique (S-DIO)

Final impressions in each group were carried out with the Elite mono-phasic additional silicone impression material (ZhermackBadia/Rovigo, Italy); in the splinted impression groups, the copings were splinted on the initial cast by Duralay acrylic resin (Duralay Corp., Tokyo, Japan) before the impression procedure. Then the abutments were separated from each other by a disk to eliminate the effect of acrylic resin shrinkage and splinted once again on the master cast during impression taking. Impressions were taken in these groups after 10 minutes. In the non-splinted groups the abutments were not splinted. The final impressions were pored with Type IV stone (Type IV Dental Stone, Zhermack, Rovigo, Italy).

Since the aim of the present study was to evaluate the dimensional differences of abutments and the accuracy of the transfer of their positions from the model to the samples, one new variable was defined for each abutment, referred to as "spatial position". This variable was under the equal influence of dimensional measurements in x, y and z axes and in case of significance of the results in each of these axes alone it was possible to evaluate the cumulative effect of all the three axes simultaneously. To this end, the center of abutment number one (zero degree) was considered the base point and the distances of the centers of other abutments from it were measured 3-dimensionally in the three axes of x, y and z.

The measurements of distances between the abutments in the three x, y and z dimensions were carried out using the Coordinate Measuring Machine (CMM) (Trimek, Reni CMM, Shaw, CMM Inc., England) at a contact accuracy of 1 μ. The 3-d measuring technique with the use of CMM is considered one of the most accurate measuring techniques for the transfer of the position of impressions, which has been used in the present study and in many other studies.[20,21]

In order to accurately register the center of each abutment and the angle of their placement, 6 points were defined on the periphery of each abutment, which resulted in the creation of a cylinder for each abutment and the intersection of the central axis of this cylinder and the horizontal plate on which the abutments were placed was considered the central point and a reference point for measuring the distances between the plates.

CMM is an accurate contact measuring device accurate to 0.1 μm with a table measuring 1×1.8 m and a sensitive probe, which moves along the width and length of the table by two horizontal and vertical arms. At one definite and standard point on the table, there exists a ball with a constant and standard diameter, which is used to calibrate the position of the probe from a 3-D point of view and also calibrate the size of its tip each time the probe is changed. The machine is kept in a room with isolated walls and equipped with an air conditioner to keep the temperature and moisture constant round the clock (Figs. 1–10).

Figure 1: The stainless steel metallic model.

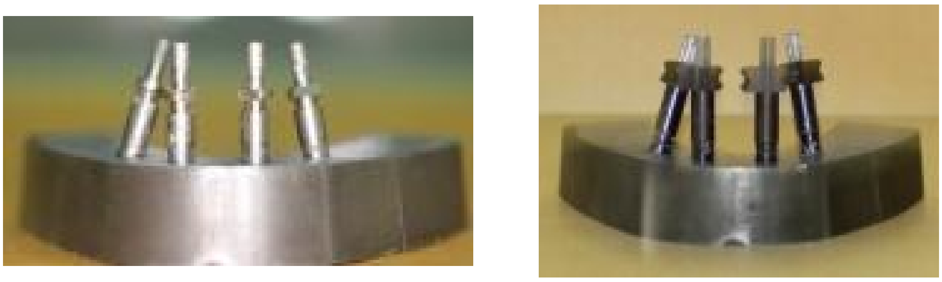

Figure 2: The impression copings in the DIO and 3I systems have been fixed and are ready for taking the impression

Figure 3: The initial impression taken with alginate

Figure 4: The initial impression which has been poured

Figure 5: Waxing up for fabricating the special tray

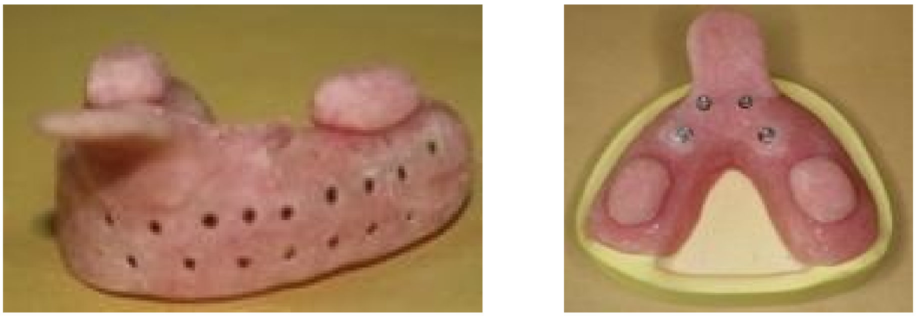

Figure 6: Fabrication of the special tray.

Figure 7: The final impression making with additional silicone

Figure 8: The final impression which has been poured

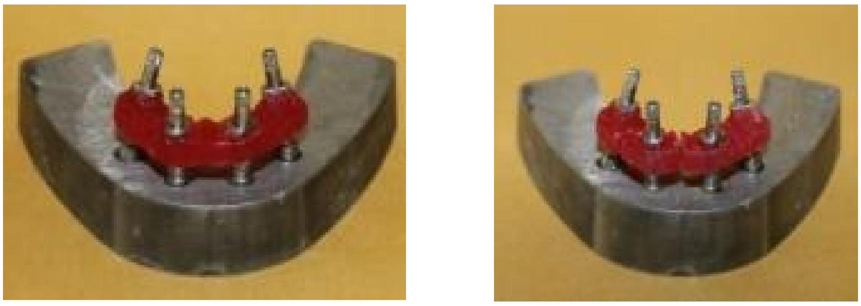

Figure 9: Splinting of the implants in the splinted technique

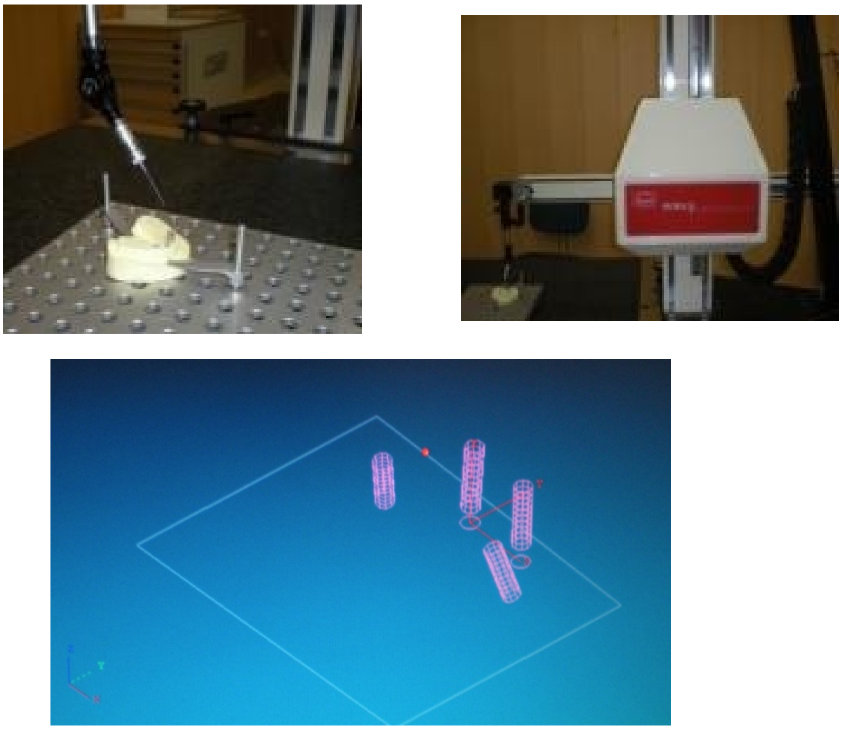

Figure 10: Coordinate measuring machine

Statistical analysis

After recording the coordinates of the center of each implant in the x, y and z axes in the two systems, in the splinted and non-splinted situations, and in different placement angles, the dimensional differences of each abutment were calculated relative to the principal abutment. None of the coordinate axes was eliminated in these calculations. Therefore, with no need to independently calculate each axis, which required elimination of data in one axis, the differences in the distances between the centers of implant abutments were used in the samples prepared relative to the abutment pins in comparison to the principal model as a criterion for the accuracy of impression procedure and transferring of the implant position from the model to the casts. SPSS 18.0 was used for statistical analysis. The differences in the coordinate values of x, y and z axes of the samples in different placement angles, splinted and non-splinted situations of copings before impression procedures and in 3I and DIO implant systems were calculated relative to coordinate values of basic vectors and the resultants of distances were calculated at the three axes. ANOVA was used for statistical analyses of data. Tukey test was used for two-by-two comparisons of the groups considering the significance of the effect of variables in this test. The amount of type I error (α) was considered to be 0.05 in this study. Statistical significance was defined at $P<0.05$.

Ethical considerations

There were no ethical issues in the present study since it was carried out in vitro.

RESULTS

1. Results of angular comparisons in S-DIO, S-3I, NS-DIO and NS-3I groups

1.1. NS-3I technique

The mean of deviation values in the principal, parallel, 15º and 25º pins relative to the control group (the metallic model) were calculated at -0.71 (±36), -0.57(±0.46), -3.0 (±38) and -2.65 (±0.35), respectively, with the parallel and 25º pins exhibiting the minimum and maximum deviations, respectively (Graph 1). The results of one-way ANOVA showed significant differences in deviations of pins in the NS-3I system ($P<0.0001$). Two-by-two comparisons using Tukey tests showed no significant differences between principal and parallel pins ($P=0.78$) and between 15º and 25º pins ($P=0.07$) in deviation. However, differences between the principal and 15º pins ($P<0.0001$), principal and 25º pins ($P<0.0001$),parallel and 15° pins ($P<0.0001$), and parallel and 25° pins ($P<0.0001$) were significant. In general, in the NS-3Isystem the deviation values were in one range in 15° and 25° pins and in another range in the parallel and principal pins.

1.2. NS-DIO technique

The means of deviation values in the principal, parallel, 15° and 25° pins were -0.87(±0.49), -0.93 (±0.44), -3.89 (±0.39) and -4.46 (±0.45), respectively, with the minimum and maximum deviation values in the principal and 25° pins, respectively (Graph 1). The results of one-way ANOVA showed significant differences in deviation values between different pins ($P<0.0001$). The results of two-by-two comparisons by Tukey tests showed no significant difference in pin deviations between principal and parallel pins (0.98); however, there were significant differences between 15° and 25° pins ($P<0.0001$), principal and 15° pins ($P<0.0001$), principal and 25° pins ($P<0.0001$), parallel and 15° pins ($P<0.0001$), and finally between parallel and 25° pins ($P<0.0001$). In general, in the NS-DIO technique, 25°, 15°, and parallel and principal pins exhibited the maximum, moderate and minimum deviation ranges, respectively.

1.3. S-3I technique

The means of deviation values in the principal, parallel, 15° and 25° pins were -.022 (±0.37), -0.25 (±0.32), -1.07 (±0.39) and -1.63 (±0.61), respectively, with the minimum and maximum deviation values in the principal and 25° pins, respectively (Graph 1). The results of one-ay ANOVA showed significant differences in deviation values in different pins with the use of S-3I system ($P<0.0001$). Two-by-two comparisons with Tukey tests showed no significant differences in deviation values between the principal and parallel pins ($P=0.99$). However, there were significant differences between 15° and 25° ($P<0.005$), principal and 15° ($P<0.0001$), principal and 25° ($P<0.0001$), parallel and 15° ($P<0.0001$) and parallel and 25° ($P<0.0001$) pins. In general, deviation values with the copings splinted before taking impressions and in the S-3I system were in the maximum, moderate and minimum ranges in 25°, 15° and in parallel and principal pins, respectively.

1.4. S-DIO technique

The mean deviation values in the principal, parallel, 15° and 25° were -.54 (±0.47), -0.49 (±0.39), -1.81 (±0.51) and -1.6 (±0.36), respectively, with the minimum and maximum deviation values in parallel and 15° pins, respectively (Graph 1). The results of one-way ANOVA showed significant differences in deviation values between different groups in the S-DIO technique ($P<0.0001$). Two-by-two comparisons by

Tukey tests showed no significant differences between the principal and parallel (P=0.99) and 15° and 25° pins (P=0.58); however, there were significant differences in deviation values between the principal and 15° (P<0.0001), principal and 25° (P<0.0001), parallel and 15° (P<0.0001) and parallel and 25° pins (P<0.0001). In general, the deviation values with the 15° and 25° pins were in one range and those in the parallel and principal pins were in another range.

2. Comparative results of distances in the 4 techniques of NS-3I, NS-DIO, S-3I and S-DIO

Evaluation of impression accuracy in terms of distances showed the following means (±SD) between pin No.1 (the principal pin) from other pins in different techniques:

2.1. NS-3I

10.27 (±0.025) mm from pin No.2; 19.09 (±0.054) mm from pin No.3; and 9.78 (±0.029) mm from pin No.4.

2.2. NS-DIO

10.27 (±0.043) mm from pin No.2; 19.18 (±18) mm from pin No. 3; and 9.8 (±0.035) mm from pin No.4.

2.3. S-3I

9.92 (±0.092) mm from pin No.2; 18.77 (±0.033) mm from pin No.3; and 9.98 (±0.019) mm from pin No.4.

2.4. S-DIO

10.19 (±0.037) mm from pin No.2; 18.93 (±0.043) mm from pin No.3; and 9.81 (±0.024) mm from pin No. 4.

One-way ANOVA showed significant differences between the study groups and the control group in distances from the principal pin (P<0.0001) (Graphs 2,3 and 4), with the minimum mean distance of all the pins from the principal pin in the S-3I technique and the maximum mean distance with the NS-DIO + NS-3I technique. The distance with the S-DIO technique was within the range of the two previous groups (Tables 1,2 and 3).

Two-by-two comparisons of the groups with post hoc Tukey tests showed significant differences in all the pins (Graphs 2,3 and 4) between SN-3I and S-3I (P<0.0001), NS-3I and S-DI (P<0.0001), NS-DIO and S-3I (P<0.0001), NS-DIO and NS-DIO (P<0.002) and S-3I and S-DIO (P<0.0001) groups; however, there were no significant differences between NS-3I and NS-DIO groups in distances from the principal pin (P=1.0) except for groups 3 (25°), in which all the differences between the groups were significant (P<0.002) (Tables 4,5 and 6).

In addition, based on the results of the study, the mean marginal deviation values of impressions in all the angles, with and without coping splinting in the 3I and DIO implant systems were -1.739 (CI: -1.654–0.57) and -2.43 (CI:-2.345 to -0.811), respectively. Therefore, impression accuracy in the 3I implant system was higher than that in the DIO system.

Furthermore, the mean marginal deviation values of impressions in all the angles and implant systems, with coping splinting, before taking impressions was -2.88 (CI: -1.711–1.711), with -1.289 (CI: -1.47–1.47) without coping splinting. Based on the results, the accuracy of impressions in the splinted technique was more than that without coping splinting.

DISCUSSION

Different techniques have been used to achieve a tension-free fit in the manufacture of implant-supported prostheses. Factors that have important roles in creating this fit in the oral cavity include a proper and accurate impression technique, prevention of distortion of impressions before they are transferred to the laboratory and accurate reconstruction of implant positions in the oral cavity. Given the problems created for dentists by angulated implants, the type of the implant system and splinting or lack of splinting of copings before taking impressions, which interfere with achieving such a fit and compromise the accuracy of impressions, the present study was undertaken to simultaneously evaluate the dimensional accuracy of 3I and DIO implant systems at 0, 15 and 25 degrees of angulations and splinting and non-splinting of attachments before impression taking.

Based on the results of the present study, the accuracy of impressions was different at different implant angulations (0, 15 and 25 degrees), with splinting and not splinting of copings before taking impressions and with different implant systems. The minimum impression errors were observed with parallel pins (0°) and the maximum was observed at 15° and 25°.Therefore, implant placement angulations, splinting or not splinting of copings before taking impressions and the type of the implant system used influenced the accuracy of impressions.

Considering the results of the present study, indicating the considerable effect of implant angulations relative to the vertical axis on the dimensional accuracy of final casts, further studies are necessary to evaluate this factor. The subject is important because in many situations in the oral cavity the implants are not placed in a straight position and take different angulations relative to the vertical axis. Meanwhile, some studies have evaluated such angulations. Assuncao et al (2004) and Carr (1992) reported that angulated implants have less dimensional accuracy compared to straight implants.[14,22] However, two other studies on 2 and 3 implants showed that implant placement angle results in no significant effect on the dimensional accuracy of the casts.[13,15] A review of the results of different studies shows that during in vitro evaluations on a large number of implants, when casts are prepared at different implant angulations, the amount of impression material distortion will increase during cast removal.[23] Conrad et al (2007) evaluated the dimensional accuracy of different impression techniques with the use of angulated implants using 3 implants placed in a triangular manner at three corners with 5, 10 and 15 degrees of divergence or convergence relative to the central implant and reported that the implant placement angulation had a significant effect on the dimensional accuracy of the casts, consistent with the results of the present study.[15] However, in the present study, 0, 15 and 25 degrees of implant angulation were evaluated to prepare casts, which were higher than the degrees evaluated in the study above. Smith (2007), too, reported that implant angle had a significant effect on the dimensional accuracy of casts with the use of closed impression technique.[24] However, in that study, the degree most probable to be encountered in the oral cavity, i.e. 5°, was not evaluated. On the other hand, Majidi and Sayahpour (2009) reported that implant placement angulation at a range of -15–15° influenced the dimensional accuracy of casts and the maximum impression errors were recorded with -10° angulation of implant for tooth #5 and -10° angulations of implant for tooth #7.[25]

In another study, Seyedan and Javan (2007) evaluated the accuracy of transferring the position of straight and angulated implants from the oral cavity to the cast with the use of closed and open tray impression techniques and polyether and polyvinyl siloxane impression materials and showed that the impression technique had no significant effect on the accuracy of transferring the position of implants with 15° implants; however, with 30° implants impressions with open tray technique were more accurate than impressions with closed tray technique.[21] They evaluated the 30°angulation which was beyond the angles evaluated in the present study; however, in both studies the 15°angulation was evaluated. Filho et al (2009) reported that use of more accurate techniques, such as prefabricated resin bars for splinting impression copings with 25° angulation, can result in similar accuracy in impressions comparable to lower degrees, which is consistent with the results of the present study to some extent.[26]

Of the techniques used to provide impressions from implants, splinted coping impression technique is more popular and exhibits higher accuracy;[27,28] however, definitive results have not been achieved with this technique in different situations. In the present study, the accuracy of the splinted technique was higher than that of the non-splinted technique by considering the distance from the parallel implant. Prithvivaj et al (2011) reviewed the effects of the use of different impression techniques and materials on the accuracy of implant impressions and reported that the accuracy of implant impressions with the splinted technique was higher compared to the non-splinted technique.[29] It is interesting that 5 studies of 7 studies which have advocated the use of the splinted technique due to its better accuracy have been published before 2003 and two have been published before 1996. It appears that modifications in the splinted technique and how the technique is carried out have decreased the distortion of the model.

To prevent displacement of impression copings during closing and opening of guiding rods and splinting of implant analogs, some researchers[30] have recommended the use of acrylic resins or other techniques, such as coated air-borne particles or abraded adhesives, to splint rectangular impression copings and therefore, they have reported that splinted impression technique is more accurate than the non-splinted impression technique. However, some other researchers have reported that splinting of impression copings with acrylic resins in the splinted technique does not increase the accuracy of impressions.[7,8,31] A lack of significant differences between the splinted and non-splinted techniques in dimensional accuracy might be attributed to a decrease in the amount of resin used during splinting of impression copings[7] to prevent polymerization shrinkage and the suitability of the properties of the impression material to preserve the stability of impression copings.[7,30,32] It has also been reported that the operator's expertise and accuracy are important for the accurate transfer of the position of impression copings by implant analogs and based on the results available in relation to the superiority of splinted or non-splinted technique, it appears the operator's expertise in using these techniques is more effective in the stability of impression copings compared to the good properties of the impression materials (polyether or additional silicone) or the potential of Duralay acrylic resin to preserve the stability of impression copings.[27] No study so far has evaluated and compared different implant systems in relation to their effect on the accuracy of impressions. Based on the results of the present study, the impressions' accuracy in the 3I system was more than that in the DIO system, which might reflect the higher accuracy of impression components of 3Isystem. In designing of impression copings of 3I system the QuickSeal splinting system has been used. This system produces a "click" sound during the seating of impression components, which might be effective in increasing the accuracy of impressions.

The results of the present study, consistent with those of other studies, showed that in none of the impression techniques, the distances measured in the master model were accurately transferred to the final cast, indicating the disruption of the spatial configuration of implants relative to each other in different dimensions.[7,30,31,33] Different factors have been reported as reasons for disruption of the spatial configuration of implant positions, including movement of metallic copings during opening and closing of guiding rods on the implants and closing of analogs,[31,34] dimensional changes of the stone used,[35] polymerization of the acrylic resin during splinting of copings with the acrylic resin,[31,34,35] dimensional changes in the impression material,[34] the depth of the implants,[36] the duration of time necessary for the use of stones,[37] the effect of the abutment–implant splinted surface[38] and the amount of machining tolerance;[39] it not possible to match all these variables in research studies.

In clinical settings, implant impression techniques are carried out with the use of impression copings; to this end, splinting is required with the implant or the abutment. In addition, after removal of the impression, another splinting is required between the impression coping and the implant analog so that the final cast can be prepared. Since the fit between these two metallic components might occur at close proximity and at different micrometer intervals, the implant impression will undoubtedly and inherently undergo dimensional changes. Ma et al (1997) termed this change as "machining tolerance" and reported its range to be 22–100µm.[40] In a systematic review by Lee et al (2008), 41 studies were evaluated and the machining tolerance range was reported to be 0.6–136 µm. Undoubtedly, components manufactured by various machines and systems are not equal in all the dimensions and there is always an acceptable range of error during the manufacture of these components, which might be considered a factor influencing the dimensional accuracy of the final implant casts, along with other factors.[3] These inevitable errors should be considered along with operator errors in the evaluation of a lack of fit between the implant and abutment. The minimum operator error in the laboratory has been report to be 30 μ and it is believed that the operator's skill in the oral cavity to identify this lack of fit decreases and his/her errors increase due to the complexity of the situation.[27] Undoubtedly, the effect of the clinical experience and expertise of the operator in research on the accuracy of impression should be further taken into account. Since the majority of studies are carried out in vitro, it appears the reported errors in such studies will significantly increase if the procedures are repeated in the oral cavity.

Various techniques have been introduced to measure dimensional changes of casts during impression procedures from implants. Three-dimensional measurement technique with the CMM machine has been used as one of the most accurate measuring techniques for the accuracy of transferring the position of impressions in the present study and in the majority of other studies.[20,21] Since the aim of the present study was to evaluate the dimensional changes of abutments and the accuracy of the transfer of their positions from the acrylic model to implant models, one new variable, referred to as the "spatial position" was used, rather than the evaluation of x and y axes separately, which is under the equal influence of dimensional measurements of x, y and z axes.[20] Despite the fact that in this technique none of the axes are evaluated separately, since the aim of the impression procedure in implant-supported prostheses is the correct transfer of the spatial configuration of implants relative to each other and to the surrounding tissues, it appears there is no need to evaluate the axes independently in clinical settings. In addition, the errors in the transfer of position are attributed to the resultant of dimensional changes in all the three axes and there is no independent cause-and-effect relationship with any of the axes. Use of various tools such as profile projector,[30] electronic sensors[41] and digital Vernier measuring tools[4] in indirect techniques, used in some research studies, has a general disadvantage which is the evaluation of all the abutments as a general unit due to the integrity of the fabricated framework and the impossibility to evaluate the position of all the abutments separately and independently. Profilometry techniques and AutoCAD software program have eliminated these disadvantages to some extent. In this context, Assuncao et al (2004) showed that these techniques have adequate accuracy in the evaluation of impression errors in models that have no angulation.[14] In addition, use of a stainless steel model results in high stability of abutments. Some studies have shown that use of metallic models,14,26,42 compared to the use of acrylic and stone models,13,15,43,44 results in higher stability in the position of model abutments. In the present study, in addition to 0, 15 and 25 degrees, two different implant systems along with splinted and non-splinted techniques of copings before impression taking with one tray type and a constant force to remove the tray were used and proper conditions were prepared to evaluate the effects of angulated implant systems and splinting and non-splinting of abutments before impression taking procedures simultaneously.

Inaccurate fitting of implant-supported prostheses might result in several biological and mechanical complications in implant treatments, leading to the failure of implant treatment and infliction of heavy financial costs on the patient. The mechanical complications of this lack of fitness consist of loosening, bending and failure of the implant and its superstructures; the biological complications consist of infectious conditions due to an increase in loading to such an extent that it will not be physiologically tolerated.[45,46] All these complications result from an unequal distribution of functional forces due to the inability to achieve a proper initial attachment at screw junctions in prostheses with inaccurate fitness.[47] Therefore, accurate impressions are important to prevent the failure of implant treatments.

CONCLUSION

The results of the present study on the effects of implant placement angulations, impression technique and the implant system on the accuracy of impressions showed the following:

– Different levels of impression accuracy were recorded at different implant placement angulations (0, 15 and 25 degrees), splinting and not splinting of copings before taking impressions and with the different implant systems.

– The mean distance from the parallel pins with the splinted coping technique before taking impressions with the 3I implant system was less than that with other techniques, indicating the accuracy of the combination of this system and technique.

– The impression accuracy in the parallel implants (without angulation) was more than that with angulated implants.

– Despite the time-consuming nature of the open tray technique along with the splinting of copings before taking impressions, this technique can be used in clinical situations because it has higher accuracy.

Limitations

– The results of the present study were achieved with only two implant systems.

– Implant angulations less than 15° and more than 25° were not evaluated in the present study.

– There were various confounding factors in the present study, which could not be completely controlled.

Recommendations

– It is recommended that the effects of implant placement angulations greater and less than the angles used in this study, such as 5° and 10°, which are more probable to be encountered in clinical settings., be evaluated on the accuracy of impressions.

– It is recommended that the effects of impression technique on impression accuracy be evaluated with the use of custom and stock trays.

– It is recommended that other implant systems be used to compare their effects on impression accuracy.

– It is finally commended that clinical studies be designed to determine the effect of implant placement angulations, different implant systems and impression techniques with different impression materials on impression accuracy.

ACKNOWLEDGEMENTS

This article was prepared from a dissertation for a specialty degree in restorative dentistry. The authors would like to extend their gratitude to the Deputy of Research at Hamadan University of Medical Sciences and the Dental Research Center for the financial support provided.

DISCLOSURE

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the paper.

REFERENCES

[1] Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part III: Problems and complications encountered. J Prosthet Dent. 1990;64:185-194.

[2] Burawi G, Houston F, Byrner P, Claffey N. A comparison of the dimensional accuracy of the splinted and unsplinted impression techniques. J Prosthet Dent. 1997;77:68-75.

[3] Zarb G, Schmitt A. The longitudinal clinical effectiveness of osseointegrated implants: The Toronto study. III. Problems and complications encountered. J Prosthet Dent. 1990;64:185-196.

[4] Cruz J, Funkenbusch P, Ercoli C, et al. Verification jig for implant supported prostheses: a comparison of standard impression with verification jigs made of different materials. J Prosthet Dent. 2002;88:329-336.

[5] Lee HJ, Lim YJ, Kim CW, et al. Accuracy of a proposed implant impression technique using abutments and metal framework. J Adv Prosthodont. 2010;2:25-31.

[6] Seyedan K, Sazgara H, Sami Kermani S, et al. Evaluation of the effect implant abutment connection type on the accuracy of impressions with open tray technique in implants placed at different angles and with two different impression materials. J Isfahan Faculty Dent 2009;5:189-197.

[7] Hsu CC, Millstein PL, Stein RS. A comparative analysis of the accuracy of implant transfer techniques. J Prosthet Dent. 1993;69:588–593.

[8] Humphries RM, Yaman P, Bloem TJ. The accuracy of implant master casts constructed from transfer impressions. Int J Oral Maxillofac Implants. 1990;5:331–336.

[9] Daoudi MF, Setchell DJ, Searson LJ. A laboratory investigation of the accuracy of the repositioning impression coping technique at the implant level for single-tooth implants. Eur J Prosthodont Restor Dent. 2003;11:23–28.

[10] Liou AD, Nicholls JI, Yuodelis RA, Brudvik JS. Accuracy of replacing three tapered transfer impression copings in two elastomeric impression materials. Int J Prosthodont 1993;6:377–383.

[11] Carr AB. Comparison of impression techniques for a five implant mandibular model. Int J Oral Maxillofac Implants. 1991;6:448–455.

[12] Assuncao WG, Tabata LF, Cardoso A, et al. Prosthetic transfer impression accuracy evaluation for osseointegrated implants. Implant Dent. 2008;17:248-256.

[13] Choi JH, Lim YJ, Yim SH, Kim CW. Evaluation of the accuracy of implant-level impression techniques for internal-connection implant prostheses in parallel and divergent models. Int J Oral Maxillofac Implants. 2007;22:761-768.

[14] Assuncao WG, Filho HG, Zaniquelli O. Evaluation of transfer impressions for osseointegrated implants at various angulations. Implant Dent. 2004;13:358-366.

[15] Conrad HJ, Pesun IJ, DeLong R, Hodges JS. Accuracy of two impression techniques with angulated implants. J Prosthet Dent. 2007;97:349-356.

[16] Assunção WG, Gomes EA, Tabata LF, Gennari-Filho H. A comparison of profilometer and AutoCAD software techniques in evaluation of implant angulation in vitro. Int J Oral Maxillofac Implants. 2008;23:618-622.

[17] Masri R. The effect of impression technique, connection type and implant angulation on impression accuracy. Int J Prosthodont. 2011;15:142-148.

[18] Pikos P, Tortopidis D, Galanis C, et al. The effect of impression technique and implant angulation on the impression accuracy of external- and internal-connection implants. Int J Oral Maxillofac Implants. 2012 ;27:1422-1428.

[19] 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.

[20] Mahshid M, Eftekhar Ashtiani R. Evaluation of the effect of impression techniques on the dimensional accuracy of final implant casts. Dental Journal of Shahid Beheshti University of Medical Sciences .2005;23:670-682.

[21] Seyedan K, Javan M. Evaluation of the accuracy of transfer of the position of implants with open and closed tray techniques with the use of polyether and polyvinyl siloxane impression materials. A specialty degree dissertation in prosthodontics. Faculty of Dentistry, Shahid Beheshti University of Medical Sciences, 2007–2008 educational year.

[22] Carr AB. Comparison of impression techniques for a two-implant 15-degree divergent model. Int J Oral Maxillofac Implants. 1992;7:468-475.

[23] Lee H, So JS, Hochstedler JL, Ercoli C. The accuracy of implant impressions: A systematic review. J Prosthet Dent. 2008;100:285-291.

[24] Smith PW. The influence of implant angulation on accuracy of dental casts. Joint Scientific Meeting of BDSR and NOF (3rd–5th April, 2007).

[25] Majidi AH, Sayahpour S. Determination of the dimensional accuracy of the major cast at different angles of placement of dental implants. A general dentistry dissertation; Faculty of Dentistry, Shahid Beheshti University of Medical Sciences, 2008–2009 educational year.

[26] Filho HG, Mazaro JV, Vedovatto E, et al. Accuracy of impression techniques for implants. Part 2 - comparison of splinting techniques. J Prosthodont. 2009;18:172-6.

[27] Assif D, Fenton A, Zarb G. Comparative accuracy of implant impression procedures. Int J Periodont Rest Dent. 1992;12:113-121.

[28] Assif D, Marshak B, Schmidt A. Accuracy of implant impression techniques. Int J Oral Maxillofac Implants. 1996;11:216-22.

[29] Prithviraj DR, Pujari ML, Garg P, Shruthi DP. Accuracy of the implant impression obtained from different impression materials and techniques: review. J Clin Exp Dent. 2011;3:e106-e111.

[30] Vigolo B, Majzoule Z, Gordiolo G. Evaluation of the accuracy of three techniques used for multiple implant abutment impressions. J Prosthet Dent. 2003;89:186-192.

[31] Spector MR, Donovan T, Nicholls JI. An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent. 1990;63:444-447.

[32] Herbst D, Nel JC, Dipdent H, et al. Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent. 2000;83:555-561.

[33] Burawi G, Houston F, Byrner P, Claffey N. A comparison of the dimensional accuracy of the splinted and unsplinted impression techniques. J Prosthet Dent. 1997;77:68-75.

[34] Phillips KM, Nicholls J, Ma T. The accuracy of three implant impression technique: A three-dimensional analysis. Int Oral Maxillofac Implants. 1994;9:533-540.

[35] Inturegui JA, Aquilino SA, Ryther JS, Lund PS. Evaluation of three impression techniques for osseointegrated oral implants. J Prosthet Dent. 1993;69:503-509.

[36] Bartlett DW, Greenwood R, Howe L. The suitability of head-of-implant and conventional abutment impression techniques for implant-retained three unit bridges: an in vitro study. Eur J Prosthodont Restor Dent. 2002;10:163-166.

[37] Lee H, Ercoli C, Funkenbusch PD. Effect of subgingival depth of implant placement on the accuracy of implant impression: an in vitro study. J Prosthet Dent. 2008;99:107-113.

[38] Holst S, Blatz MB, Bergler M, et al. Influence of impression material and time on the 3-dimensional accuracy of implant impressions. Quintessence Int. 2007;38:67-73.

[39] Binon PP. Evaluation of machine accuracy and consistency of selected implants, standard abutments and laboratory analogues. Int J Prosthodont. 1995;8:162-178.

[40] Ma T, Nicholls JI, Rubenstein JE. Tolerance measurements of various implant components. Int J Oral Maxillofac Implants. 1997;12:371-375.

[41] Naconecy MM, Teixeira ER, Shinkai RS, et al. Evaluation of the accuracy of 3 transfer techniques for implant-supported prostheses with multiple abutments. Int J Oral Maxillofac Implants. 2004;19:192-198.

[42] Cabral LM, Guedes CG. Comparative analysis of 4 impression techniques for implants. Implant Dent. 2007;16:187-194.

[43] Vigolo P, Fonzi F, Majzoub Z, Cordioli G. An evaluation of impression techniques for multiple internal connection implant prostheses. J Prosthet Dent. 2004;92:470-476.

[44] Wenz HJ, Hertrampf K. Accuracy of impressions and casts using different implant impression techniques in a multiimplant system with an internal hex connection. Int J Oral Maxillofac Implants. 2008;23:39-47.

[45] Tolman DE, Laney WR. Tissue-integrated prosthesis complications. Int J Oral Maxillofac Implants.1992;7:477-484.

[46] Clancy J, Koorbusch G, Bogacki M. Retrospective analysis of dental implant patients: 1983-1988. J Dent Res. 1991;70:487-488.

[47] Rengert B, Jemt T, Jorneus L. Forces and moments on Brånemark implants. Int J Oral Maxillofac Implants. 1990;4:241-247.