

Effect of Arch Size and Implant Angulations on the Accuracy of Implant Impressions

Keywords

Impression Accuracy
Dental Implant
Angled Implant
Arch Size

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ABSTRACT

Purpose: To evaluate the effects of arch size and implant angulation on the accuracy of implant impressions. *Materials and Methods:* Four different resin models (small and large) of edentulous maxilla were fabricated and four implants were inserted (Blossom®, Ø 4.75 × 10 mm) in each model. Implants were either parallel or angled 25° buccally. Forty working casts (small parallel, small angled, large parallel, and large angled) were fabricated in dental stone (n=10). For each implant, linear and angular displacements were measured using a coordinate-measuring machine (CMM) and mean values were analyzed by univariate analysis ($\alpha = 0.05$). *Results:* Arch size did not affect the linear or angular displacement ($P > .05$). However, the implant angulation had a marked influence on the linear displacement ($P < .05$). The largest linear displacement occurred in implant no. 4 of angled small groups. *Conclusion:* Regardless of arch size, linear and angular accuracy of implant impression varied with the implant angulation.

INTRODUCTION

Implant-supported restorations are a well-established treatment in oral rehabilitation. Existing evidence supports the increasing number of implant-supported prostheses in dental practices.¹

Nevertheless, many implant failures occur after loading. Exposure of the implant/abutment components to excessive force is regarded as a contributing factor to these failures.² Two significant sources of overloading in implant prostheses are occlusal overload and lack of passivity. Implants lack periodontal ligaments and are more rigid than natural teeth. Therefore, lack of passive fit results in a continuous static force on the implant, abutment, and restoration components. Biological complications include periimplantitis and loss of osseointegration, while mechanical complications include screw loosening, abutment fracture, and restoration flexure and fracture.^{3,4} Hence, fabrication of an implant suprastructure with a passive fit is crucial.

Achieving a passive or ideal fit has been shown to be practically impossible under clinical conditions.⁵ However, attempts should be made to minimize the degree of errors at each stage of prosthetic fabrication. Implant impression is the first step in transferring the three-dimensional (3D) position of implants from the mouth to the laboratory to the fabrication of the working cast.⁶ Numerous studies have focused on the factors influencing impressions, working models, and suprastructures with the good passive fit. Some of these factors include impression technique, method of

Received: 02.01.2021

Accepted: 02.04.2021

doi:10.1922/EJPRD.2274MirMohammadRezaei05

connecting impression components (splinted vs. unsplinted), type of impression material, depth of implant placement, type of implant connection (internal vs. external).⁷ In particular, several studies investigated the effects of implant angulation on the impression's accuracy and working cast, although a consistent conclusion could not be drawn. For example, although implant angulation did not have a significant influence on impression accuracy when two or three implants were examined,^{8,9} studies that incorporated a higher number of implants reported significant effects.^{10,11} In cases with multiple implants, the number, angulation, and inter-implant distance were identified as substantial influencing factors in achieving accurate impressions and frameworks.¹²

To achieve an accurate impression, the impression material should be sufficiently stiff that the impression copings can be held stably in the impression material. Simultaneously, the copings should be removed from the mouth without too much strain and deformation of the impression material. In other words, the impression material should be sufficiently elastic that it returns to its initial dimensions without significant distortion upon removing from dental or implant undercuts. This "elastic recovery" of impression materials is more difficult to achieve when deep undercuts, increased implant angulation, and thinner impression materials are used, such as in cases with a narrow arch or small distance between implants. Under otherwise identical conditions, less elastic recovery will occur in implants placed in small arches.¹² Therefore, arch size that affects inter-implant length in different dimensions (anterior-posterior and cross-arch) may influence impression accuracy and subsequently poured working cast. To the best of the authors' knowledge, no study to date has investigated the effects of arch size on the accuracy of impressions of implants with different angulations. Therefore, the present study aimed to examine the impact of arch size and implant angulation on the impression's accuracy. Our null hypotheses were that neither arch size nor implant angulation would affect the accuracy of the produced working casts.

MATERIALS AND METHODS

For fabricating the large master models, a large-sized cast of an edentulous patient was fitted to the largest sized stock tray (no. 35 Edentulous Stock Tray, Border-Lock, Clan Dental, Maarheeze, Netherlands). To ensure approximately similar anatomy and tissue undercuts in the small models, the large cast was duplicated and modified by sectioning anterior-posteriorly and medio-laterally from the middle of the large cast. The four pieces were reduced in size until they fit into the smallest stock tray (Border-Lock) glued together. A pair of each model was duplicated in clear cold-cured acrylic resin (Acrosun) to generate resin master models.^{9,11} The inter-canine distance and inter-molar distance were 25 mm and 45 mm respectively, in small and 35 mm and 50 mm respectively, in large models.

The master models were designed to simulate a clinical scenario involving a maxillary implant-supported overdenture.¹³ Four tissue-level implants with internal-hex connections (Blossom®, Ø 4.75 × 10 mm) were placed in the locations of the canines and first molars, resulting in four groups: large parallel implants (LP), large angled implants (LA), small parallel implants (SP), and small angled implants (SA). Angled implants were placed at an angle of 25° buccally using an implant navigation system (IMPLA 3D-THETA). Implants were numbered as no. 1 (at the right first molar site), no. 2 (right canine site), no. 3 (left canine site) and no. 4 (left first molar site). Also, a stainless-steel solid cylinder (5 mm × 10 mm, diameter × height) was attached in each model's center and used as a reference point in subsequent measurements (Figure 1).



Figure 1: Two representatives of large and small master models.

To fabricate the custom trays, an impression was made from each model using stock trays and elastomeric impression material (Monopren). After 30 minutes, the impression was poured with type IV dental stone (Fuji Rock). Forty custom trays, the open-tray technique were made using a visible light-cured acrylic resin (Triad) with a 3-mm relief and three tissue stops (one in anterior and two in posterior) away from implants. The custom trays had windows at the implant sites to provide access to the impression copings' transfer pin. Trays were left for 24 hours at room temperature. A universal tray adhesive (Elite Iperlink LCT) was evenly applied to the inner surface of trays 15 minutes before impressions were made. Pick-up impression copings (IHOTTW Open-Tray Transfer) were installed with 10-N-cm torque. Impressions were taken by using a polyvinyl siloxane impression material (Monopren Kettenbach GmbH & Co. KG, Heerfeld, Eschenburg, Germany). Impression procedures were performed in an incubator chamber (99% humidity and 35 °C) with a 5-kg weight maintained on the top of trays during the setting to simulate the oral condition. After 4 minutes, the transfer pins of impression copings were unscrewed, and the tray was removed and examined for any flaws, separation from the tray, or imperfect mixing, and was stored for 1 hour at room temperature. Implant analogs (IHAW) were attached to the impression copings and were poured in type IV dental stone (Fuji Rock, GC Co., Tokyo, Japan). Forty casts were designated to the four groups

(n = 10) according to the arch size and implant angulation. A pre-study power analysis was performed, and the sample size was calculated using SPSS software (IBM SPSS), based on the mean value, the standard deviation of data derived in a previous study.¹⁰ For an effect size of 0.4, an alpha error of 0.05 and power of 80%, ten specimens were computed in each group.

A coordinate-measuring machine (CMM) (DEA Mistral) running an analyzing software (Reflex) was used to measure the linear and rotational deviation between the master models and corresponding working casts, with an accuracy of 0.002 mm.

The Part Coordinated System was defined as follows: the machine's ruby probe (1 mm in diameter) hit the upper edge of the stainless-steel cylinder at 4 points, and a circular plane was constructed. The center of the circle was set as the coordinate origin, and its planar surface was considered as the reference XY plane. Similarly, the centroid of all implants was constructed. A straight line from the origin to the centroid of implant no. 1 (right first molar location) was set as Y-axis. Z-axis was constructed by a straight line passed through the origin, perpendicular to the XY plane (Figure 2). The analyzing software (Reflex) developed a digital duplication of the position of four implants in each model and working casts for the measurements.

Linear displacement (ΔR) of each implant in the working casts compared to the master models was calculated by the formula $\Delta R = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}$. To measure the change in angular rotation, impression copings (ISOTT open tray transfer, SQ Platform/Intra-Lock, Boca Raton, FL, USA) were inserted in the casts and master models. The impression copings' flat surface was found by the machine probe hitting 4 points and projecting a circle onto it. A normal vector (R_{θ}) to this plane was projected to the coordinate system. The difference between the normal vectors of the corresponding implants (ΔR_{θ}) in groups was reported as the angular displacement. Each measurement was done three times, and mean data of ΔR and ΔR_{θ} . The univariate analysis of variance between working casts and master models was analyzed at two levels (arch size and implant angle). Statistical analyses were performed using the SPSS software package (IBM SPSS Statistics V 22.0, SPSS, Inc., New York, USA) at a confidence level of 95%.

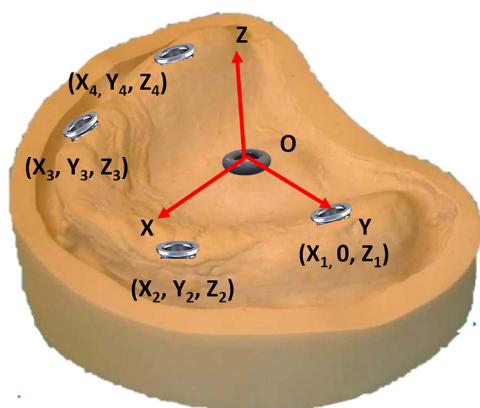


Figure 2: Part Coordinate System on the models. Point O is the center of reference metal cylinder and origin of the system. The defined coordinates of each implant are shown.

RESULTS

Mean differences and standard deviations of linear and angular displacements of the four implants between the working casts and master models are summarized in Table 1. Univariate analysis showed that arch size did not influence the four implants' linear and angular displacements ($P > .05$). However, the angulation of the implant showed a significant effect on linear displacement ($P < .05$). Implant no. 4 was significantly displaced in models of both the large and small arch sizes ($P = .029$). The largest linear displacement occurred in implant no. 4 of angled small groups.

DISCUSSION

The present study investigated the accuracy of impressions in models with parallel and angled implants and large and small sizes in an edentulous maxilla. Based on this study's results, the null hypothesis that the arch size would not affect the implants' linear or angular displacement was accepted. The null hypothesis that the implants' angulation would not affect linear or angular deviation was rejected.

Many previous studies have examined implant impressions' accuracy, considering such factors as impression technique, implant system, angulation, and insertion depth. However, in many of those studies, simple non-anatomical models were used.^{7,14-16} A model that lacks curvature or tissue undercuts cannot replicate the deformation that occurs when an impression is taken in the mouth.⁶ Therefore, the present study used a patient model with anatomic landmarks and undercuts, and implants were inserted around the arches like the clinical scenario of maxillary overdenture. In addition, attempts were made to reproduce the intraoral conditions by placing specimens in the incubator and under a force of 5 kg.⁶

Impression copings were not splinted to each other in this study. A systematic review of impression techniques by Lee *et al.*⁴ revealed no consensus for splinted vs un-splinted impression techniques. However, in a situation where implants were inserted with a buccal tilt, studies showed that the rigidity of splinted internal-connection impression copings might make removal of the copings very difficult.^{9,17} Therefore, impression copings were left un-splinted in the present study. Angled and parallel implants were placed in separate arches to detect the effect of implants' angulation on the deformation of impression material.

Our result showed that angulation had a significant effect on the linear deviation of one of the posterior implants (no. 4) that is consistent with Akalin *et al.*,⁶ Sorrentino *et al.*,⁶ Mpikos *et al.*,¹⁶ Richi *et al.*¹⁷ The force necessary for removal of an impression coping connected to an angled implant was greater than for a parallel implant. This factor probably resulted in greater displacement with angled implants. Greater applied force means that the impression material is subjected to more considerable compressive and tensile tensions. Depending on the degree of elastic recovery of the impression, this situation can result in more deformation of the impression material and

Table 1. Mean \pm standard deviation of (ΔR) $_{\theta}$ and ΔR between working casts and master models in all groups

Arch size	Implant location number	ΔR_{θ} (degree)		ΔR (micron)	
		Parallel	Angled	Parallel	Angled
Small	1	0.389 \pm 0.321	0.357 \pm 0.350	136 \pm 62	97 \pm 64
	2	0.787 \pm 0.591	0.614 \pm 0.416	212 \pm 111	175 \pm 134
	3	0.473 \pm 0.356	0.328 \pm 0.202	168 \pm 42	179 \pm 168
	4	0.207 \pm 0.15	0.641 \pm 0.153	148 \pm 80	311 \pm 211
Large	1	0.415 \pm 0.399	0.475 \pm 0.860	122 \pm 72	104 \pm 69
	2	0.451 \pm 0.209	0.685 \pm 1.202	146 \pm 90	217 \pm 141
	3	0.346 \pm 0.489	0.668 \pm 1.047	126 \pm 66	235 \pm 155
	4	0.899 \pm 0.575	0.537 \pm 1.022	181 \pm 22	193 \pm 92

the impression copings' displacement. On the contrary, implant angulation showed no effect on the impression accuracy in studies by Hazboun *et al.*¹¹ and Jo *et al.*¹⁸ Difference in implant systems and connections, model shapes, implant angulation amount and direction (buccal vs mesio-distal), impression materials and measurement techniques may result in different findings.

In the present study, there was no difference between displacement of implants in the large and small working casts. Although no similar study was found for comparison, Akalin *et al.*⁶ evaluated the effect of arch curvature width and implant angulation on implant impressions accuracy.⁶ Six implants with internal connections were inserted in anterior and posterior sites of an edentulous maxillary model. They assumed that the arch width was wider when implants were placed posteriorly. Despite differences in methods and materials, their finding was comparable to that of the present study in that implants placed on the broader region of the arch showed no significant difference in most conditions, whereas angulation (10° buccally) played a significant role in the displacement of implants.

Significant displacement was observed in only one of the posterior implants (no. 4) in the angled model. Hazebourn *et al.*¹¹ and Rubenstein *et al.*¹⁹ likewise found that posterior implants (terminal implants) were exposed to a higher risk of displacement due to higher removal stress. Moreover, considering our model with angled implants on both sides of the arch, removing the impression tray must start from one side (e.g., right or left, depending on the operator's dominant hand) and continue to the other side of the arch. As a result, the final posterior implant (specifically, implant no. 4) was removed with greater applied stress. A question may arise of why linear changes were not significant in implant no. 1. This result could be due to our method of measurement, in which the reference for Y coordinates was set to zero in implant no. 1.⁶

In the current study, the posterior implant's linear displacement in the angled small group was higher than large group though it was not significant. Sorrentino *et al.*¹⁰ explained that

the exit pathway in a larger arch likely imposes less stress on impression copings and material because the tray's rotational radius is larger for removal from the mouth. It may imply that in a clinical scenario facing a small maxillary arch size (comparable to the current study i.e. around the inter-canine distance and inter-molar distance of 25 mm and 45 mm, respectively), splinting should be taken to secure a more accurate result. However, this suggestion should be investigated in further study.

There are different opinions as to what degree of misfit is clinically essential. Kahramanoglu²⁰ reported a 103- μ m misfit, and Riedy *et al.*²¹ considered a 125- μ m misfit as clinically acceptable. Klineberg *et al.*²² reported a misfit of over 30 μ m in more than 10% of the abutment interface as unacceptable. However, a gap of fewer than 60 μ m could not be detected visually Jemt *et al.*²³ suggested a misfit of less than 150 μ m as acceptable. The amount of linear displacement achieved in our study is within the acceptable range, except for the small angled models for which the mean value in implant no. 4 was around 311 μ m.

Notwithstanding, in the clinical situation, a framework fabricated on the model with even one significantly displaced implant will probably fail to fit passively. Furthermore, there are inherent limitations to using the CMM to measure the linear displacement of implants in working casts.²⁴ For example, displacement is typically reported as a net absolute distance. It may be possible that two similar linear displacements differ in one or two coordinates (i.e., X, Y, or Z). Therefore, the interpretation of linear displacement seems complicated. Considering the various techniques and approaches in measuring deviations, it seems most practical to fabricate a framework and verify any misfit of those models that require further studies.

In this study, direct impression technique and pick-up impression copings were used, which requires greater force upon removal. Using indirect impression technique with closed tray impression technique may result in different results that deserve further study.

CONCLUSION

Within the limitation of the present study, the impression accuracy of edentulous maxillary was not affected by arch size. Although, angled abutment led to less accurate working models.

ACKNOWLEDGEMENT

The authors express special thanks to Dandal Inc., Intra-Lock Implant System Int., Iran for its generous supply of implant components. We are also grateful to Dr. Thierry Giorno for his valuable assistance in reviewing the manuscript.

This research was supported by grant no. 29973 from Tehran University of Medical Sciences & Health Services.

MANUFACTURERS' DETAILS

- Stock tray; no. 35 Edentulous Stock Tray, Border-Lock, Clan Dental, Maarheeze, Netherlands.
- Cold-cured acrylic resin; Acrosun, Betadent Co., Tehran, Iran.
- Tissue-level implant; Blossom®, Ø 4.75 × 10 mm, IntraHex, Intra-Lock International, Boca Raton, FL, USA.
- Implant navigation system; IMPLA 3D-THETA, Schutz, Germany.
- Impression material; Monopren Kettenbach Gm BH & Co. KG, Heerfeld, Eschenburg, Germany.
- Type IV dental stone; Fuji Rock, GC Co., Tokyo, Japan.
- Visible light-cured acrylic resin; Triad, Dentsply Sirona, PA, USA.
- Universal tray adhesive; Elite Iperlink LCT, Zhermack, Badia Polesine, Italy.
- Pick-up impression copings; IHOTTW Open-Tray Transfer, IntraHex Wide Platform, 4.5mm, Intra-Lock, Boca Raton, FL, USA.
- Implant analogs; IHAW, Intra Lock International, Boca Raton, FL, USA.
- SPSS software; IBM SPSS Statistics V 22.0, SPSS, Inc., New York, USA.
- Coordinate-measuring machine; DEA Mistral, Brown & Sharpe Inc., Grugliasco, Italy.
- analyzing software; Reflex, Brown & Sharpe Inc., USA.

REFERENCE

1. Pan Yu, Tsoi, J.K.H., Lam, W.Y.H and Pow, E.H. Implant framework misfit: A systematic review on assessment methods and clinical complications. *Clin Implant Dent Relat Res.* 2020; Dec 16. doi: 10.1111/cid.12968.
2. Romanos, G.E., Delgado-Ruiz, R. and Sculean, A. Concepts for prevention of complications in implant therapy. *Periodontol 2000* 2019;**81**:7-17.
3. Katsoulis, J., Takeichi, T., Sol Gaviriria, A., Peter, L. and Katsoulis, K. Misfit of implant prostheses and its impact on clinical outcomes. Definition, assessment, and a systematic review of the literature. *Eur J Oral Implantol* 2017;**10**:121-138.
4. Lee, H., So, J.S., Hochstedler, J. and Ercoli, C. The accuracy of implant impressions: a systematic review. *J Prosthet Dent* 2008;**100**:285-291.
5. Koyano, K. and Esaki, D. Occlusion on oral implants: current clinical guidelines. *J Oral Rehabil* 2015;**42**:153-161.
6. Akalin, Z.F., Ozkan, Y.K. and Ekerim, A. Effects of implant angulation, impression material, and variation in arch curvature width on implant transfer model accuracy. *Int J Oral Maxillofac Implant* 2013;**28**:149-157.
7. Choi, J.-H., Lim, Y.-J. and Kim, C.-W. Evaluation of the accuracy of implant-level impression techniques for internal-connection implant prostheses in parallel and divergent models. *Int J Oral Maxillofac Implant* 2007;**22**:761-768.
8. Humphries, R.M., Yaman, P. and Bloem, T.J. The accuracy of implant master casts constructed from transfer impressions. *Int J Oral Maxillofac Implant* 1990;**5**:331-336.
9. Vigolo, P., Fonzi, F., Majzoub, Z. and Cordioli, G. An evaluation of impression techniques for multiple internal connection implant prostheses. *J Prosthet Dent* 2004;**92**:470-476.
10. Sorrentino, R., Gherlone, E.F., Calesini G. and Zarone, F. Effect of implant angulation, connection length, and impression material on the dimensional accuracy of implant impressions: an *in vitro* comparative study. *Clin Implant Dent Relat Res* 2010;**12**:e63-e76.
11. Hazboun, G.B.A., Masri, R., Romberg, E., Kempfer, J. and Driscoll, C.F. Effect of implant angulation and impression technique on impressions of NobelActive implants. *J Prosthet Dent* 2015;**113**:425-431.
12. Lawson, N.C., Burgess, J.O. and Litaker, M.S. Tensile elastic recovery of elastomeric impression materials. *J Prosthet Dent* 2008;**100**:29-33
13. Misch, C.E. *Dental Implant Prosthetic*. 2nd ed., St. Louis, Mosby, Elsevier; 2015, p 753-765.
14. Rutkunas, V., Sveikata, K. and Savickas, R. Effect of implant angulation, material selection, and impression technique on impression accuracy; a preliminary laboratory study. *Int J Prosthodont* 2012;**25**:512-515.
15. Conrad, H.J., Pesun, I.J., Delong, R. and Hodges, J.S. Accuracy of two impression techniques with angulated implants. *J Prosthet Dent* 2007;**97**:349-356.
16. Mpikos, P., Kafantaris, N., Tortopidis, D., Galanis, C. and Kiodis, P. 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.
17. Richi, M.W., Kurtulmus-Yilmaz, S. and Ozan, O. Comparison of the accuracy of different impression procedures in case of multiple and angulated implants: Accuracy of impressions in multiple and angulated implants. *Head Face Med.* 2020;**16**:1-12.
18. Jo, S.H., Kim, K., Seo, J.M., Kwang, Y.S., Park, J.M. and Ahn, S.G. Effect of impression coping and implant angulation on the accuracy of implant impression: an *in vitro* study. *J Adv Prosthodont* 2010;**2**:128-133.
19. Rubenstein, J.E. and Lowry, M.B. A comparison of two solder registration materials: a three-dimensional analysis. *J Prosthet Dent* 2006;**95**:379-391.
20. Kahramanoglu, E. and Kulak-Ozkan, Y. Marginal and internal adaptation of different superstructure and abutment materials using two different implant systems for five-unit implant-supported fixed partial dentures: an *in vitro* study. *Int J Oral Maxillofac Implants* 2013;**28**:1207-1216.
21. Riedy, S.J., Lang, B.R. and Lang, B.E. Fit of implant frameworks fabricated by different techniques. *J Prosthet Dent* 1997;**78**:596-604.
22. Klineberg, I.J. and Murray, G. Design of superstructures for osseointegrated fixtures. *Swed Dent J Suppl.* 1985;**28**:63-69.
23. Jemt, T. and Book, K. Prosthesis misfit and marginal bone loss in edentulous implant patients. *Int J Oral Maxillofac Implant* 1996;**11**:620-625.
24. Kim, J.-H., Kim, K.R. and Kim, S. Critical appraisal of implant impression accuracies: a systematic review. *J Prosthet Dent* 2015;**114**:185-192.