J Dent Mater Tech 2025; 14 (4): 180-185
DOI: 10.22038/JDMT.2025.90296.1869

J Dent Mater Tech

Original Article

Open Access

Accuracy of conventional splinted and non-splinted impression techniques for angulated implants in an edentulous mandibular model

Mohammadreza Nakhaei[1], Hamidreza Rajati Haghi[1], Saied Sabzevari[1], Mohammad Shirdel[2]*

Abstract

Objective: This in vitro study aimed to compare the accuracy of splinted versus non-splinted open-tray impression techniques for angulated implants in an edentulous mandibular model.

Methods: In this in vitro study, three acrylic edentulous mandibular models were used, each containing three implants placed at angulations of 0°, 15°, and 25°. Five impressions were obtained from each model using either splinted or non-splinted open-tray techniques (n=5 per technique/angulation, total n=30). The impressions were made using polyvinyl siloxane with either splinted or non-splinted copings. Reference scans obtained from a laboratory scanner served as the gold standard. Three-dimensional (3D) deviations between test and reference datasets were measured using Geomagic Control X software, and the results were analyzed by two-way ANOVA at the significance level of $P<0.05$.

Results: The mean 3D deviations were 57.90 ± 12.65 µm for non-splinted impressions and 61.84 ± 15.84 µm for splinted impressions. The mean deviation was lowest at 15° (56.38 ± 14.83 µm) and highest at 25° (64.44 ± 14.62 µm). No significant difference was observed in the accuracy of different impression techniques ($P=0.535$). Furthermore, implant angulation did not significantly affect impression accuracy ($P=0.401$).

Conclusions: Within the limitations of this study, the splinted open-tray technique demonstrated comparable accuracy to the non-splinted technique. Implant angulation up to 25° did not significantly affect the precision of splinted and non-splinted open-tray impressions.

Keywords: Dental implants, Dental impression technique, Dental prosthesis, Implant-supported dental prostheses, Splints

Introduction

Implant-supported prostheses have become the preferred option for masticatory rehabilitation because they provide predictable functional and aesthetic outcomes. Successful rehabilitation of edentulous patients with implant-supported prostheses depends on achieving a passive fit between the prosthetic framework and the underlying implants. A misfit can induce biomechanical stresses, leading to complications such as screw loosening, peri-implant bone loss, and implant fracture (1).

The initial step in achieving a passive fit between the prosthetic framework and the underlying implants is the accurate transfer of the three-dimensional (3D) implant positions from the patient's mouth to the working casts (1, 2). Several variables can affect transfer accuracy, including implant characteristics (number, angulation, and depth), the impression technique, and the use of coping splinting methods (3).

Among the available impression techniques, the open-tray method using polyvinyl siloxane or polyether is widely accepted for multiple implants (4-6). However, the inherent dimensional instability of impression materials has led clinicians to recommend rigid splinting to maintain the spatial relationships between coping (7). As a result, various rigid splinting materials have been investigated, with autopolymerizing acrylic resin being the most commonly used material (3, 8, 9).

The effect of splinting on impression accuracy remains controversial. In a systematic review by Baig (3), 24 studies were evaluated; ten reported no significant difference between splinted and non-splinted techniques, seven supported the superior accuracy of the splinted technique, and six showed mixed results. Another study found that splinting provided a better

[1] Department of Prosthodontics, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.
[2] Dental Research Center, Mashhad University of Medical Sciences, Mashhad, Iran.

*Corresponding Author: Mohammad Shirdel
Email: mshirdelir@yahoo.com

Accepted: 19 November 2025. Submitted: 9 August 2025.

passive fit in the maxilla but showed no statistically superior fit in the mandible (10). Furthermore, Ma et al. (11) suggested that splinted copings produced significantly larger marginal gaps than non-splinted ones, suggesting the superiority of the non-splinting technique. In contrast, Richi et al. (1) reported that splinting the impression copings enhanced the accuracy of the impression technique.

In clinical practice, parallel implant placement is frequently restricted by anatomical constraints and aesthetic requirements (1). In edentulous cases, implants are often placed at varying angulations to optimize bone support, avoid anatomical structures such as the mental foramen, and achieve favorable prosthetic emergence profiles. Although some studies have examined the accuracy of splinted and non-splinted open tray impression techniques, there is limited data regarding their application in cases involving angled implants (12).

This study aimed to compare the accuracy of splinted and non-splinted open-tray impression techniques for angulated implants in an edentulous mandibular model. The study tested the following null hypotheses: first, there would be no statistically significant difference in the 3D accuracy of implant analog positions between the splinted open-tray and non-splinted open-tray techniques; and second, implant angulation (0°, 15°, and 25°) would have no significant effect on the accuracy of each impression technique.

Materials and methods

This in vitro study was approved by the ethics committee of Mashhad University of Medical Sciences (IR.MUMS.DENTISTRY.REC123456).

Model preparation

Three acrylic edentulous mandibular models with identical dimensions were fabricated. Using a custom surgical guide, implant sites were marked at three positions: one in the middle (C) and two distal to the middle point (A & E; Figure 1) (18). A milling machine (Nouvac AG, Goldach, Switzerland) was used to prepare osteotomies in three angulation configurations:

Model 1: All implants were placed parallel (0°).

Model 2: A 15° buccolingual divergence was created between implants A and C, and a 15° mesiodistal divergence between implants A and E.

Model 3: A 25° buccolingual divergence was created between implants A and C, and a 25° mesiodistal divergence between implants A and E.

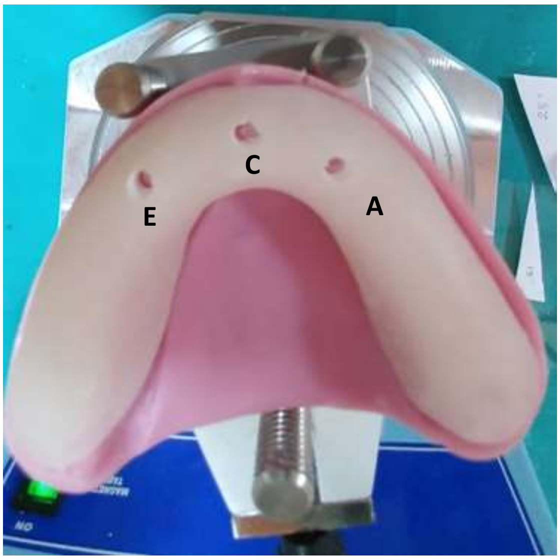

Figure 1. Acrylic resin cast with surgical guide

The angulations were controlled using the machine's tilting table, which was calibrated with a smartphone gyroscope application.

Three B2 Ø4.1/14 mm internal-connection implants (Biodenta Swiss, Berneck, Switzerland) were secured in each model using autopolymerizing acrylic resin (Figure 2). To ensure reproducible tray positioning, a peripheral resin seat was fabricated around each model. Custom impression trays with three 5 × 5 mm openings were prepared.

Impression techniques

Five impressions were obtained from each model using two techniques (n=15 per technique, total n=30):

Group A (Non-splinted impression technique): Square open-tray copings (Biodenta Swiss) were finger-tightened onto the implants. A custom impression tray was loaded with high-viscosity polyvinyl siloxane (Putty Fast Set; Panasil, Kettenbach, Germany). Light-body material (Initial Contact X-Light; Panasil) was then injected around the copings on the model. The assembly was placed in an incubator at 35°C for 8 minutes (13).

The set impression was removed, and implant analogs were connected. After a 4-hour setting period at room temperature, the impressions were poured with type IV dental stone (Elite rock; Badia Polesine, Zhermack Rovigo, Italy). The casts were stored at room temperature for one week before analysis.

Group B (Splinted impression technique): A cast was made according to the protocol explained in group 1 to form the splinting framework. The copings were connected using dental floss (Mina, Iran) as a scaffold. Duralay resin (Reliance Dental Mfg Co, Wort, IL, USA) was applied around the dental floss (Figure 3). After 20

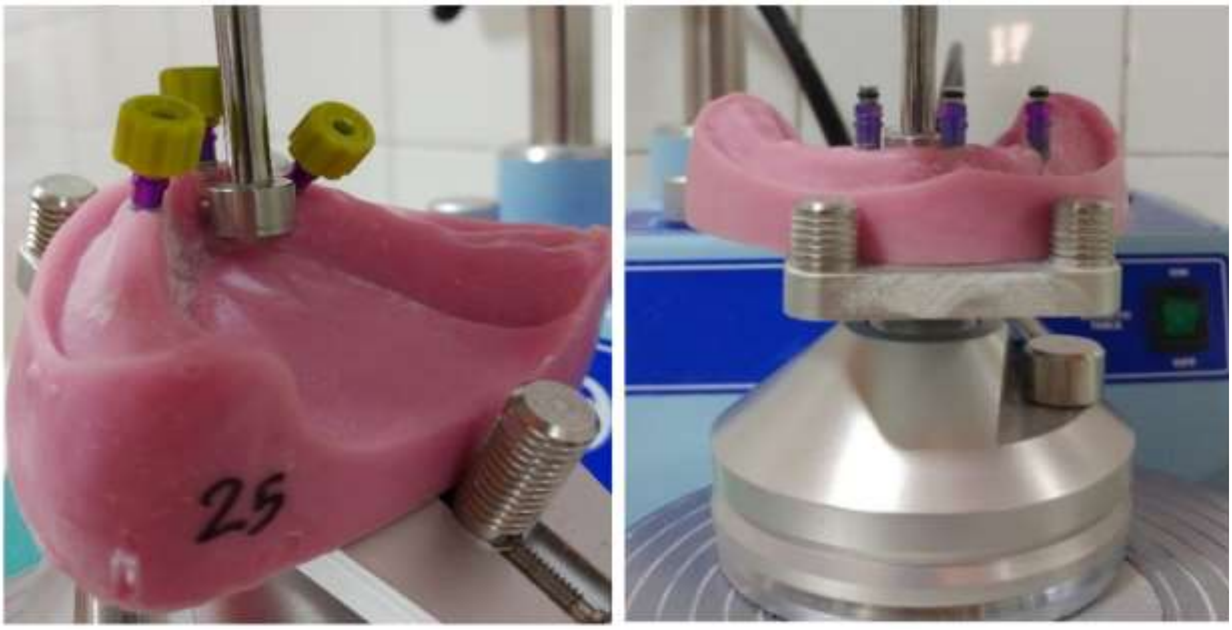

Figure 2. Implant placement. 0-degree model (right) and 25-degree model (left)

Figure 3. Splinting the impression copings (left) and separating the resin bar using a cutting disk (right)

minutes, the framework was sectioned using a disk and allowed to set for 24 hours.

For the final impression, the sectioned splint was carefully positioned on the master model, and the impression copings were secured within it. The two-sectioned parts of the splint were then reconnected using fresh Duralay resin. After 5 minutes, the impression was taken using the same procedure as in Group A.

Reference scans

After attaching the scan bodies (Figure 4), the casts and master models were scanned using a high-precision laboratory scanner (Smart optics Activity 885, Smart optics, Bochum, Germany) with 6 µm accuracy (14). These reference scans served as the gold standard. The STL files of the casts were compared with their corresponding master models using Geomagic Control X (3D Systems, Rock Hill, SC, USA). To reduce potential dimensional distortion errors, only the geometries of the three scan bodies were used for superimposition, while the other regions of the mandible were excluded. For superimposition of the scan bodies, the best-fit algorithm was applied (13). Subsequently, by superimposing the files obtained from the casts and the corresponding master model, the average spatial deviation (Average deviation) of the scan bodies in all three spatial dimensions was calculated (15).

Statistical analysis

Data analysis was performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY,

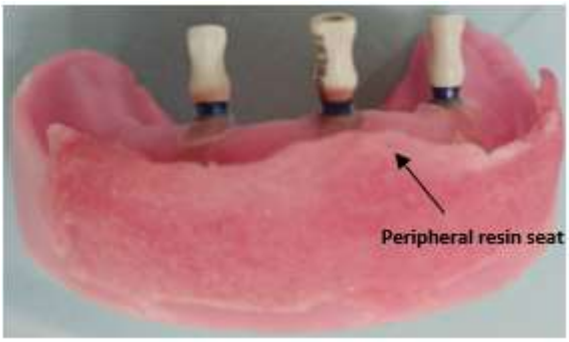

Figure 4. Attached scan bodies on the resin cast surrounded by a peripheral resin seat

USA). The normality of the data was confirmed using the Shapiro-Wilk test (P>0.05). A two-way analysis of variance (ANOVA) was used to assess the effects of the impression technique and implant angulation (0°, 15°, 25°) on impression accuracy. A P-value less than 0.05 was considered statistically significant.

Results

The descriptive data for the 3D deviations across the study groups are summarized in Table 1. The non-splinted technique had a lower mean deviation (57.90 ± 12.65 µm), compared to the splinted technique (61.84 ± 15.84 µm). The mean deviation was lowest at 15° (56.38 ± 14.83 µm) and highest at 25° (64.44 ± 14.62 µm).

Two-way ANOVA indicated that implant angulation did not have any significant effect on the accuracy of the impression technique (P=0.401). Moreover, no significant difference was observed among different impression techniques regarding their accuracy (P=0.535). There was no significant interaction between impression technique and implant angulation (P=0.383).

In the non-splinted group, the mean deviation increased with increasing angulation. The splinted group exhibited an initial decrease in deviation from 0° to 15°, followed by an increase at 25°.

Discussion

This in vitro study evaluated the accuracy of splinted open-tray and non-splinted open-tray impression techniques for recording angulated implants in edentulous mandibular models. "The results showed no significant difference in accuracy between the splinted and non-splinted impression techniques, nor between different implant angulations. Therefore, the null hypotheses were accepted.

The findings of this study align with several investigations that reported comparable accuracy between splinted and non-splinted open-tray techniques (14, 16, 17). A systematic review by Pesce et al. (18) suggested that the pick-up technique is adequate for up to three implants without splinting, while splinting is recommended for more than three implants to ensure accurate transfer of spatial relationships to stone casts. Lee et al. (19) suggested that acrylic resin splinting often presents clinical difficulties in obtaining an accurate impression due to its time-consuming nature and the risk of material distortion. In contrast to the outcomes of this study, Akca and Çehreli (20) reported that the splinting technique for implant impressions yields greater accuracy, which contributes to improved long-term stability of the implants. Richi et al. (1) reported that the splinted technique had lower deviations compared to the non-splinted one.

The lack of a significant difference in accuracy between the splinted and non-splinted techniques may be attributed to the limited number of implants (three per model). Furthermore, using rigid acrylic models eliminated soft tissue resilience and movement, which are factors that could contribute to impression distortion during tray removal in the clinical setting. Additionally, the positioning of implants at sites A, C, and E may have minimized the cumulative dimensional changes caused by polymerization shrinkage of the impression material. Site C was positioned centrally on

Table 1. Mean ± standard deviation (SD) of 3D deviations (µm) between test and reference datasets across angulations and impression techniques

Group	0°	15°	25°	Total
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Splinted	65.55 ± 7.97	57.67 ± 13.56	64.03 ± 7.59	61.84 ± 15.84
Non-splinted	52.00 ± 15.09	55.10 ± 17.51	64.86 ± 20.56	57.90 ± 12.65
Total	58.77 ± 13.43	56.38 ± 14.83	64.44 ± 14.62	59.87 ± 14.23

Effect of angulation: F = 0.967, P = 0.401
Effect of group: F = 0.420, P = 0.535
Interaction (angulation × group): F = 1.02, P = 0.383

the mandibular model, while Sites A and E were symmetrically placed on the distal sides, forming a balanced triangular pattern with short inter-implant distances. By keeping the implants closer together, the study minimized the total distance affected by shrinkage.

Implant angulation (0°, 15°, 25°) showed no significant effect on impression accuracy for either splinted or non-splinted techniques. This finding aligns with previous research by Choi et al. (21), who reported that implant angulation up to 25° does not compromise the accuracy of conventional impression methods. The outcomes of this study are in contrast to those of other studies that demonstrated the splinting technique and implant angulation would affect the accuracy of impressions (5, 10). These studies used higher angulations or more implants and attributed the increased accuracy of the splinted technique to reduced movement of the copings during impression removal and analog attachment (5, 10). Richi et al. (1) examined the accuracy of open-tray impressions in edentulous maxillary models with six implants, comparing parallel placement (0°) to angulations of 10° and 20°. Their results showed that implant angulation significantly affected impression accuracy, with deviations increasing as the angulation rose from 0° to 20°. This contrasting result is likely due to the use of greater implants (six compared to three in this study), which may increase cumulative distortion.

The absence of angulation-related errors in the present study may also be attributed to the design of the square impression copings, which provide rotational stability and prevent misalignment during impression removal. Additionally, the open-tray technique ensures that impression copings remain rigidly connected to the implant analogs after tray removal, preserving their spatial orientation regardless of the initial implant angulation.

The present findings suggest that clinicians can place implants at angulations up to 25° without compromisimg impression accuracy when using conventional open-tray techniques. This study has some limitations. The in vitro design does not fully replicate clinical conditions such as soft tissue resilience, patient movement, and limited intraoral access. Additionally, testing only one splinting material (Duralay resin) limits the generalizability of the results to other splinting methods. Future studies should include clinical validations with a variety of splinting materials and full-arch implant configurations.

Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Splinting impression copings with Duralay resin did not significantly improve the accuracy of open-tray impressions compared to non-splinted copings.
2- Implant angulation up to 25° did not significantly affect the accuracy of either splinted or non-splinted impression techniques.
3- Overall, these findings suggest that for edentulous arches with angulated implants, splinting may not be necessary for up to three implants with angulations up to 25 degrees.

Acknowledgements

Not applicable.

Conflicts of interest

The authors declare no conflict of interest.

Ethical considerations

This in vitro study was approved by the ethics committee of Mashhad University of Medical Sciences (IR.MUMS.DENTISTRY.REC123456).

Author contributions

M.R.N. and H.R.H. contributed to the design and supervision of the research; S.S. assisted with the conceptualization of the study, data collection, and data analysis; and M.S. contributed to the research implementation and writing of the manuscript. All authors read and approved the final manuscript.

Funding

The present study was funded by the vice-chancellor for research at Mashhad University of Medical Sciences (Thesis number: 625).

References

1. Richi MW, Kurtulmus-Yilmaz S, Ozan O. Comparison of the accuracy of different impression procedures in case of multiple and angulated implants. Head Face Med 2020;16(1):1-12.
2. Mukhopadhyay P, Khalikar A, Wankhade S, Deogade S, Shende R. The passive fit concept-A review of methods to achieve and evaluate in multiple unit implant supported screw retained prosthesis. J Dent Oral Sci 2021;3(2):1-7.

3. Baig MR. Accuracy of impressions of multiple implants in the edentulous arch: a systematic review. Int J Oral Maxillofac Implants 2014;29(4):869-880.
4. Moreira AH, Rodrigues NF, Pinho AC, Fonseca JC, Vilaça JL. Accuracy comparison of implant impression techniques: a systematic review. Clin Implant Dent Relat Res 2015;17:e751-e764.
5. Papaspyridakos P, Chen C-J, Gallucci GO, Doukoudakis A, Weber H-P, Chronopoulos V. Accuracy of implant impressions for partially and completely edentulous patients: a systematic review. Int J Oral Maxillofac Implants 2014;29(4): 836-845.
6. Moazzami SM, Alizadeh S, Sarvari S. Natural Tooth Pontic and FRC splint Using Special Rigid Tray Technique (A Case Report). J Dent Mater Tech 15;4(4):137-144.
7. Rutkunas V, Bilius V, Simonaitis T, Auskalnis L, Jurgilevicius J, Akulauskas M. The effect of different implant impression splinting techniques and time on the dimensional accuracy: an in vitro study. J Dent 2022;126:104267.
8. Neshandar M, Baloch F, Mousavisedighi S, Bitaraf T. Evaluation of the Effect of Two Types of Autopolymerizing Acrylic Resin Splints on Dimensional Accuracy in Open Tray Impression Technique. J Res Dent Maxillofac Sci 2019;4(4):23-27.
9. Negahdari R, Barzegar A, Milani AM, Ahmadi YS, Rahbar M. Comparison of the accuracy of fixture-level implant impressions using two different materials for splinting. J Adv Periodontol Implant Dent 2022;14(2):134.
10. Algabri RS, Altayyar SA, Abo-Alrejal HO, Alsourori AA, Alshaibani DA, Mostafa MH. Effect of primary versus secondary splinting impression techniques on the passive fit of screw-retained implant prosthesis: a randomized clinical trial. Bull Natl Res Cent 2023;47(1):164.
11. Ma Y, Al-Radhi RYZ, Jiang L, Yu H. Does Splinting the Direct Copings Increase the Impression Accuracy of Two-Unit Nonparallel Implant Restorations? A Systematic Review and Meta-analysis. Int J Oral Maxillofac Implants 2022; 37(4):653-659.
12. Keerthna M, Jain AR. Comparison of dimensional accuracy of implant cast of multiple angled implants by splinted and non-splinted methods-an in vitro study. Drug Invention Today 2018;10(4):1-5.
13. Güth J-F, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect data capturing. Clin oral investig 2013;17(4):1201-1208.
14. Kurtulmus-Yilmaz S, Ozan O, Ozcelik TB, Yagiz A. Digital evaluation of the accuracy of impression techniques and materials in angulated implants. J Dent 2014;42(12):1551-1559.
15. Stimmelmayr M, Erdelt K, Güth J-F, Happe A, Beuer F. Evaluation of impression accuracy for a four-implant mandibular model—a digital approach. Clin Oral Investig 2012;16(4):1137-1142.
16. Elshenawy EA, Alam-Eldein AM, Abd Elfatah FA. Cast accuracy obtained from different impression techniques at different implant angulations (in vitro study). Int J Implant Dent 2018;4(1):9.
17. de Avila ÉD, Chagas Amaral ÂL, Pereira Pinelli LA, de Assis Mollo Jr F. Comparison of the accuracy of plastic and metal stock trays for implant impressions. Int J Oral Maxillofac Implants 2012; 27(3):544-550.
18. Pesce P, Nicolini P, Caponio VCA, Zecca PA, Canullo L, Isola G, et al. Accuracy of full-arch intraoral scans versus conventional impression: A systematic review with a meta-analysis and a proposal to standardise the analysis of the accuracy. J Clin Med 2024;14(1):71.
19. Lee H, Ercoli C, Funkenbusch PD, Feng C. Effect of subgingival depth of implant placement on the dimensional accuracy of the implant impression: an in vitro study. J Prosthet Dent 2008;99(2):107-113.
20. Akca K, Çehreli MC. Accuracy of 2 impression techniques for ITI implants. Int J Oral Maxillofac Implants 2004;19(4):517-523.
21. Choi J-H, Lim Y-J, 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 Implants 2007;22(5):761-768.
22. Abduo J, Palamara JE. Accuracy of digital impressions versus conventional impressions for 2 implants: an in vitro study evaluating the effect of implant angulation. Int J Implant Dent 2021;7(1):75.