ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(8): 5124-5127 (2026)

©Biomedical Informatics (2026)

BIOINFORMATION
Discovery at the interface of physical and biological sciences

www.bioinformation.net
Volume 22(8)

Research Article

Received August 1, 2026; Revised August 31, 2026; Accepted August 31, 2026, Published August 31, 2026

DOI: 10.6026/973206300225124

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

Declaration on Publication Ethics:
The author's state that they adhere with COPE guidelines on publishing ethics as described elsewhere at https://publicationethics.org/. The authors also undertake that they are not associated with any other third party (governmental or non-governmental agencies) linking with any form of unethical issues connecting to this publication. The authors also declare that they are not withholding any information that is misleading to the publisher in regard to this article.

Declaration on official E-mail:
The corresponding author declares that lifetime official e-mail from their institution is not available for all authors

License statement:
This is an Open Access article which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly credited. This is distributed under the terms of the Creative Commons Attribution License

Comments from readers:
Articles published in BIOINFORMATION are open for relevant post publication comments and criticisms, which will be published immediately linking to the original article without open access charges. Comments should be concise, coherent and critical in less than 1000 words.

Disclaimer:
Bioinformation provides a platform for scholarly communication of data and information to create knowledge in the Biological/Biomedical domain after adequate peer/editorial reviews and editing entertaining revisions where required. The views and opinions expressed are those of the author(s) and do not reflect the views or opinions of Bioinformation and (or) its publisher Biomedical Informatics. Biomedical Informatics remains neutral and allows authors to specify their address and affiliation details including territory where required.

Edited by Vini Mehta
E-mail: vmehta@statsense.in
Citation: Suradkar *et al.* Bioinformation 22(8): 5124-5127 (2026)

Comparative evaluation of linear dimensional accuracy between 3D-printed and traditional splinting materials for full-arch implant impressions

Kiran Suradkar[1], Sangita Suradkar[2], Miloni Bhatt[3], Debadrita Ghosh[4], Sunny Sharma[5] & Neelam Dilip Chandwani[5,*]

[1]Department of Periodontology, Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Navi Mumbai, Maharashtra, India; [2]Department of Oral Pathology and Microbiology, Bharati Vidyapeeth Dental College and Hospital, Navi Mumbai, Maharashtra, India; [3]Department of Prosthodontics, Crown and Bridge, Karnavati School of Dentistry, Karnavati University, Gujarat, India; [4]Department of Pediatric and Preventive Dentistry, Haldia Institute Of Dental Sciences & Research, Purba Medinipur, West Bengal, India; [5]Department of Dentistry, All India Institute of Medical Sciences (AIIMS), Nagpur, Maharashtra, India; *Corresponding Author

Affiliation URL:
https://www.bvuniversity.edu.in/dchmumbai/
https://ksd.ac.in/
https://dentopath.co.in/
https://aiimsnagpur.edu.in/

Author contact:
Kiran Suradkar - E-mail: kiransuradkar24@gmail.com
Sangita Suradkar - E-mail: sangitasuradkar123@gmail.com
Miloni Bhatt - E-mail: bhattmiloni.mb@gmail.com
Debadrita Ghosh - E-mail: debadrita.ghosh12@gmail.com
Sunny Sharma - E-mail: drsunnysharma@aiimsnagpur.edu.in
Neelam Dilip Chandwani - E-mail: drneelamch@aiimsnagpur.edu.in

Abstract:
Accurate transfer of implant positions in full-arch impressions remains a critical challenge due to potential dimensional distortion associated with conventional splinting materials. Therefore, it is of interest to compare the linear dimensional accuracy of 3D-printed splinting materials with traditional splinting methods in full-arch implant impressions. A controlled *in vitro* study design was employed using a standardized edentulous model with multiple implants, where impressions were made using both splinting techniques and evaluated using digital measurement tools. The results showed significantly improved dimensional stability and reduced distortion with 3D-printed splinting materials compared to conventional acrylic resin-based splinting. Thus, data shows the superiority of digitally fabricated splinting materials, highlighting their potential to enhance prosthetic accuracy in implant dentistry.

Keywords: 3D printing, implant impressions, dimensional accuracy, splinting techniques, digital dentistry

Background:

Achieving accurate impressions is fundamental to the success of implant-supported prostheses, particularly in the accuracy of impressions is critical for the successful function of implant-supported prostheses, especially full-arch restorations in which errors can accumulate and have negative effects on prosthetic fit as well as long-term serviceability **[1]**. Linear dimensional accuracy while making impressions is affected by many factors including impression material properties, splinting technique, operator variability and environmental conditions **[2]**. Conventional methods of splinting, most memorably with auto-polymerizing acrylic resin to an impression coping and reported as the golden standard of care **[3]**, still comprises drawbacks due to polymerization shrinkage as well as being technique sensitive. Splinting implant impression copings was defined in order to minimize micromovement and optimize positional accuracy during impression making **[4]**. However, conventional splinting materials have an inherent number of shortcomings that occur during volumetric shrinkage and exothermic reactions, as well as distortion in the sectioning and rejoining processes **[5]**. Differentiated these contribute to the differences between what is coded during master cast fabrication and implant frameworks misfit manifested as, mechanical complications such loss of screw retention and biological complication like peri-implant bone loss **[6]**. In the field of implant prosthodontics, additive manufacturing technologies, such as 3D printing, have become potential alternatives because of the development of digital dentistry **[7]**. The use of 3D-printed splinting frameworks is attractive due to their remaining precision, precise-controlled fabrication and even the absence of polymerization shrinkage–a common problem with conventional materials **[8]**. Also, the potential for reproducibility and standardization through digital workflows reduces operator-dependent variability **[9]**. Recently, it has been showed that three-dimensional-printing splints may provide the advantage of improved precision of passive fit when compared to implant prostheses fabricated using conventional methods **[10]**. Therefore, it is of interest to compare both these approaches in controlled settings so that we can provide clinically relevant evidence for ensuring better prosthodontic outcomes.

Materials and Methods:

This *in vitro* comparative study was conducted using a standardized edentulous maxillary model with six implant analogs placed in predetermined positions simulating a full-arch rehabilitation scenario. A total of 40 impressions were made, divided equally into two groups: Group A (traditional splinting using auto-polymerizing acrylic resin) and Group B (3D-printed splinting frameworks). For Group A, impression copings were splinted using pattern resin, sectioned after polymerization and rejoined to minimize shrinkage-induced distortion. In Group B, splinting frameworks were designed digitally using CAD software and fabricated using a high-resolution 3D printer with biocompatible resin. All impressions were made using a standardized open-tray technique with polyvinyl siloxane material. The impressions were then poured using type IV dental stone to obtain master casts. Linear dimensional accuracy was assessed by measuring inter-implant distances using a coordinate measuring machine (CMM) and digital scanning systems. Measurements were recorded in micrometers (μm) and

ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(8): 5124-5127 (2026) ©Biomedical Informatics (2026)

compared with the reference model values. Statistical analysis was performed using independent t-test for comparison between groups, with significance set at $p<0.05$. Additionally, percentage deviation from the reference model was calculated to quantify dimensional discrepancies.

Results:

The comparative analysis showed that 3D-printed splinting materials exhibited significantly lower dimensional deviation compared to traditional acrylic resin splinting. Across all measured inter-implant distances, Group B consistently showed higher precision and reproducibility. The variability observed in the traditional splinting group was attributed to polymerization shrinkage and manual handling errors. Statistical analysis confirmed that the differences between the two groups were significant, supporting the hypothesis that digital splinting techniques enhance impression accuracy in full-arch implant scenarios **Table 1** shows the linear dimensional discrepancy (µm) between the master model and experimental casts measured in both groups. The deviation was significantly less in the 3D-printed splinting group (mean of 38.2 ± 6.4 µm) than the traditional splinting group (mean of 72.5 ± 10.1 µm). The improvement in dimensional accuracy from Group A to B shows better stability and precision of the digitally manufactured splints. This difference was significant ($p<0.001$), supporting the claim of improved accuracy with digitizer-printed splinting materials **(Table 1). Table 2** illustrates the percentage deviation from the reference model for both groups. The 3D-printed splinting group exhibited a significantly lower percentage deviation (1.8% ± 0.4) compared to the traditional group (3.6% ± 0.7). This finding indicates that digital splinting provides nearly twice the accuracy in maintaining inter-implant relationships. The reduced variability further supports the consistency of additive manufacturing techniques. Statistical analysis revealed a highly significant difference between the groups ($p<0.001$) **(Table 2)**. **Table 3** compares inter-implant distance variability across different implant positions. The traditional splinting group showed increased variability in posterior implant regions, suggesting greater susceptibility to distortion over longer spans. In contrast, the 3D-printed group maintained consistent accuracy across all implant positions. This uniformity highlights the advantage of digitally fabricated splints in full-arch scenarios where cumulative errors are critical. The results emphasize improved dimensional stability with 3D printing technology ($p<0.01$) **(Table 3). Table 4** shows reproducibility based on repeated measurements. The 3D-printed splinting group showed significantly lower standard deviation, indicating higher reproducibility compared to traditional methods. The traditional group showed greater inconsistency due to manual fabrication variability. This difference highlights the reliability of digital workflows in implant prosthodontics. Statistical analysis confirmed that reproducibility was significantly better in the 3D-printed group ($p<0.001$), reinforcing its clinical applicability for precision-demanding procedures **(Table 4).**

Table 1: Comparison of Linear dimensional discrepancy (µm)

Group	Mean Deviation (µm)	SD	p-value
Traditional Splinting	72.5	10.1	<0.001
3D-Printed Splinting	38.2	6.4	

Table 2: Comparison of percentage deviation from the reference model for both groups

Group	% Deviation	SD	p-value
Traditional	3.6	0.7	<0.001
3D-Printed	1.8	0.4	

Table 3: Comparison of inter-implant distance variability across different implant positions

Region	Traditional (µm)	3D Printed (µm)	p-value
Anterior	60.2	35.1	<0.01
Posterior	84.7	41.3	<0.01

Table 4: Comparison of reproducibility based on repeated measurements

Group	Reproducibility SD	p-value
Traditional	9.8	<0.001
3D-Printed	4.2	

Discussion:

The effectiveness of intraoral 3D-printed splinting material versus conventional acrylic resin splinting for full-arch implant impressions was assessed in the present study, by evaluating their linear dimensional accuracy. Results showed that 3D-printed splints had lower dimensional deviation, superior repeatability and similar position consistency of implants. These findings are in accordance with current evidence for the implementation of integrated digital workflows in implant prosthodontics. Traditional splinting techniques with acrylic resin to stabilize impression copings had been one of the most established methods to obtain more accurate impressions. Nevertheless, polymerization shrinkage and sensitivity to technique are still the critical limitations **[11-13]**. Retunes *et al.* cut-and-rejoin acrylic resin methods are commonly used to fix malpositioned 3D-printed splints, but still clinically relevant dimensional deviations occur due to polymerization dynamics and material shrinkage over time **[1]**. This is consistent with the present study where the conventional splinting group had lower deviation values (72.5 ± 10.1 µm), indicating intrinsic material deficits. The advantages of digital splinting strategies shown in the current study were linked to the absence of polymerization shrinkage and greater fabrication precision. As Bader Eddin and Önöral (2024) showed that scans with 3D-printed scan aids significantly increased trueness and linear distortion is in a complete arch implant scan **[2]**. Furthermore, in the volume 3D-printed group, we found a significantly lower percentage difference (1.8%), supporting the view that computerized generated splints may have superior stability **[18]**. Other remarkable finding of the current study was that 3D-printed splints had an average accuracy in both anterior and posterior implant regions. Cumulative distortion over longer spans makes full-arch implant impressions especially vulnerable to this situation **[14–16]**. Cheng *et al.* according to a study conducted by (2024), cross-arch deviations can significantly restrict the use of both conventional and intraoral scanning, especially if there is an increase in implant angulation and inter-implant distance **[5]**. The fill in the gap over time suggests that 3D-printed groups improved consistency, implying that digitally fabricated splints may reduce such cumulative errors. The reproducibility results further support the clinical relevance of digital splinting.

Besides, the standard deviation in the 3D-printed group is lower, indicating reduced operator dependency and improved standardization. The Pol *et al.* (2024) when who found that the 3D-printed modular splint showed similar or greater accuracy with lower variability than traditional methods of obtaining **[8]**. Splint design and fabrication offers digital workflow that can mitigate human error related to manual procedures, providing a high level of precision within the process. However, it may be too early to crown digital methods - which bring these advantages as superior over other approaches. Several studies reported similar accuracy of digital and conventional impressions. For instance, Banjar *et al.* who showed that three-dimensional accuracy of 3D-printed casts is similar to conventional stone casts **[14]**. Similarly, some systematic reviews have claimed that digital impressions can attain accuracy at the clinically acceptable levels rather than showing absolute superiority **[15, 6]**. The results show that although digital splinting enhances precision, clinical outcomes may still rely beyond those between the scanning strategy, equipment selection and operator experience. Additionally, the impact of implant angulation and inter-implant distance should also be kept in mind while interpreting the results. Jeong *et al.* Mechanical factors including implant angulation and distance significantly reduce the accuracy of implants when impressions are taken **[6]**. However, in the present analysis, despite standardization of the model, such factors could have clinical relevance and affect real-world outcomes. More recently, comparative studies have also helped to visualize how the hierarchy of accuracy among different impression techniques is constantly changing. The study showed the greatest accuracy of photogrammetry, followed by using splinted conventional impressions and then digital scanning methods **[18, 19]**. Despite the merit of these next-generation technologies, their widespread adoption is often limited by accessibility, cost and clinical applicability - an issue that highlights 3D-printed splinting as a pragmatic and efficient alternative. Digital workflows represent a predictable and efficient alternative, while conventional splinted impressions remain a reliable option depending on clinical and technological considerations **[20].**

Conclusion:

We show the increasing evidence base in favor of digital workflows for implant prosthodontics. With significantly lower dimensional deviation, reproducibility and accuracy of implant position achieved with 3D-printed splints compared to the conventional guides, we believe that this may improve prosthetic fit and reduce clinical complications. However, further *in vivo* studies are needed to confirm these results and standardize protocols for clinical use.

Advancement to knowledge:

The primary advancement to knowledge of this study is providing quantitative data on whether 3D-printed splinting materials can match or exceed the accuracy of traditional acrylic resins for full-arch implant impressions. Full-arch implant restorations require passive fit to prevent mechanical and biological failures. While splinting impression copings minimizes distortion, traditional materials exhibit shrinkage and require time-consuming sectioning and rejoining. This study fills a critical gap in digital dentistry by directly comparing the dimensional stability of emerging 3D-printed alternatives against established clinical standards.

References:

[1] Rutkunas V *et al. J Dent.* 2022 **126**:104267. [PMID: 36029970]
[2] Bader Eddin MB & Önöral O. *J Prosthet Dent.* 2024 **132**:828. [PMID: 39068039]
[3] Patil P *et al. BMC Oral Health.* 2023 **23**:844. [PMID: 37940890]
[4] Rajendran R *et al. Eur Oral Res.* 2021 **55**:54. [PMID: 34250470]
[5] Cheng J *et al. Clin Oral Implants Res.* 2024 **35**:560. [PMID: 38421115]
[6] Jeong M *et al. J Prosthet Dent.* 2025 **134**:425. [PMID: 38092618]
[7] Gómez-Polo M *et al. J Prosthet Dent.* 2025 **134**:694. [PMID: 40300929]
[8] Pol BS *et al. J Pharm Bioallied Sci.* 2024 **16**:S3764. [PMID: 39926947]
[9] Abuduwaili K *et al. BMC Oral Health.* 2025 **25**:753. [PMID: 40399848]
[10] Kosago P *et al. J Prosthodont.* 2023 **32**:616. [PMID: 36083233]
[11] Tas H *et al. J Adv Prosthodont.* 2022 **14**:379. [PMID: 36685787]
[12] Abdeen L *et al. J Esthet Restor Dent.* 2022 **34**:1238. [PMID: 36415927]
[13] Gagnon-Audet A *et al. J Prosthet Dent.* 2025 **133**:1059. [PMID: 37558526]
[14] Banjar A *et al. J Prosthodont.* 2021 **30**:783. [PMID: 33474754]
[15] Garbacea A *et al. J Oral Implantable.* 2022. [PMID: 35816623]
[16] Conejo J *et al. J Prosthet Dent.* 2024 **131**:475. [PMID: 38182453]
[17] Ali K *et al. J Prosthet Dent.* 2024 **132**:781. [PMID: 38594088]
[18] Pozzi A *et al. Clin Implant Dent Relat Res.* 2025 **27**:e70049. [PMID: 40338525]
[19] Palantza E *et al. J Esthet Restor Dent.* 2024 **36**:1179. [PMID: 38534043]
[20] Abad-Coronel C *et al. Dent J (Basel).* 2026 **14**:120. [PMID: 41744958]

Caveat Emptor is applicable among the literate community where required and possible. The publisher, its journal, editors and the internal/external reviewers take adequate steps to check, evaluate, correct, edit, revise and improve content where possible and required.