Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 3182-3186 | ISSN:2251-6727

3D Printing in Dentistry: Revolutionizing Oral Prosthetics and Implants

Dr. Varsha B Aher[1*], Dr. Ramsay Muthukumar[2], Dr. Neeta Sinha[3], Dr. Devendra Chopra[4], Dr. Sarita Singh[5], Dr. Alok Suman[6]

[1*]MDS (Oral Medicine and Radiology), Dr. D. Y. Patil Dental College & Hospital, Nerul, Navi Mumbai, Maharashtra, India

[2]Reader, Department of Oral and Maxillofacial Surgery, Sri Venkateshwaraa Dental College, Villupuram Main Road, Ariyur, Puducherry, India

[3]Professor, Department of Prosthodontics and Crown & Bridge, Buddha Institute of Dental Sciences & Hospital, M G Nagar, Kanti Factory Road, Kankarbagh, Patna, Bihar, India

[4]Professor and Head, Department of Prosthodontics and Crown & Bridge, Saraswati Dental College and Hospital, Lucknow, Uttar Pradesh - 226028, India

[5]Associate Professor, Department of Prosthodontics and Crown & Bridge, Buddha Institute of Dental Sciences & Hospital, M G Nagar, Kanti Factory Road, Kankarbagh, Patna, Bihar, India

[6]Assistant Professor, Department of Prosthodontics and Crown & Bridge, Buddha Institute of Dental Sciences & Hospital, M G Nagar, Kanti Factory Road, Kankarbagh, Patna, Bihar, India

***Corresponding Author:**

Dr. Varsha B Aher

MDS (Oral Medicine and Radiology), Dr. D. Y. Patil Dental College & Hospital, Nerul, Navi Mumbai, Maharashtra, India

(Received: 27 September 2025 Revised: 05 October 2025 Accepted: 14 October 2025)

KEYWORDS

3D printing, prosthodontics, dental implants, CAD-CAM, additive manufacturing

ABSTRACT:

Aim

The purpose of this study was to compare the clinical performance of implant-supported restorations and 3D-printed prostheses to traditional fabrication methods and CAD-CAM milling in a hospital setting.

Methodology

Three groups of 50 patients were randomly assigned: 15 patients received CAD-CAM, 15 received conventional techniques, and 20 patients received 3D printing. Marginal fit, fabrication time, patient satisfaction, and complication rate during a 12-month follow-up were among the outcomes that were measured.

Results

Outperforming CAD-CAM and traditional methods, 3D-printed restorations demonstrated the best results with the lowest marginal discrepancy (52.7 µm), shortest fabrication time (4.2 h), highest patient satisfaction (VAS 9.2), and lowest complication rate (5%).

Conclusion

Compared to CAD-CAM and traditional fabrication, 3D printing showed better accuracy, efficiency, and patient-centered results. One dependable substitute for contemporary restorative workflows is additive manufacturing.

Background

Additive manufacturing, commonly referred to as three-dimensional (3D) printing, has become one of the most revolutionary developments in contemporary dentistry. The technology makes it possible to fabricate surgical instruments and highly customised dental prosthetics with a degree of precision and repeatability that

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 3182-3186 | ISSN:2251-6727

conventional techniques frequently fall short of. Its potential to transform patient care by decreasing chairside time, improving prosthetic precision, and expediting clinical workflows was highlighted in early investigations into its dental applications (Dawood et al., 2015) [1]. These early realisations positioned 3D printing as a disruptive force that could transform dental practice, rather than just as an additional tool. The use of polymeric materials for the creation of dental prostheses has greatly increased in the prosthodontics field as a result of advancements in additive manufacturing. According to Revilla-León and Özcan (2019) [2], these materials have expanded the range of prosthetic applications, enabling clinicians to offer treatment options that strike a balance between functional performance and cost-effectiveness. In contrast to conventional subtractive manufacturing, additive methods allow for more design flexibility and less material waste, which supports sustainable clinical practices. This change has also created new opportunities for digital workflows, combining 3D printing, computer-aided design (CAD), and intraoral scanning into a smooth clinical process. 3D printing has also had a significant impact on implant dentistry. According to Revilla-León et al. (2020) [3], 3D-printed polymer-based components improve functional predictability and design accuracy, especially in surgical guides and temporary restorations. These developments enhance patient-specific treatment outcomes, decrease surgical invasiveness, and increase implant placement accuracy. Furthermore, these applications show how digital implant planning and additive manufacturing work together to create a fully integrated digital workflow from diagnosis to rehabilitation. However, the factors that affect accuracy and clinical performance are just as important to the success of 3D printing in dentistry as the technology itself. Variables like printer type, printing resolution, and post-processing methods were emphasised by Tian et al. (2021) [4] as crucial factors that affect the final product's quality. Their results highlight the necessity of optimisation and standardisation to guarantee reliable clinical results. With the accuracy that 3D printing provides, clinical protocols have also changed to become more patient-specific and minimally invasive. According to Prasad et al. (2018) [5], the use of additive manufacturing in dentistry has made it easier to create customised treatment plans, improving patient comfort and treatment effectiveness. These methods are in line with the more general objectives of contemporary dentistry, which prioritise better patient satisfaction, shorter treatment times, and the preservation of natural tissues. More recently, 3D printing has been used for definitive restorations in addition to temporary and experimental prosthetics. Rezaie et al. (2023) [6] showed that improved mechanical performance and marginal adaptation are two new clinical advantages of using additive manufacturing to fabricate dental prostheses. These results represent a significant shift from experimental application to broad clinical adoption. At the same time, Huang et al. (2023) [7] found that additive manufacturing was a promising addition to oral implant clinics, offering enhancements in clinical precision and workflow efficiency. The growing acceptance of 3D printing as a dependable and essential part of implantology is highlighted by their review. All of these advancements highlight how crucial 3D printing will be in determining the direction of dental implantology and prosthetics in the future. 3D printing has developed from a cutting-edge invention into a vital component of modern dentistry by incorporating digital workflows, improving customisation, and assisting patient-centered treatment plans.

Methodology

From January 2024 to May 2025, the Department of Prosthodontics hosted this prospective hospital-based clinical study. Assessing the precision, effectiveness, and patient-centered results of 3D-printed prostheses and implant-supported restorations in contrast to traditional fabrication methods was the main goal. Prior to inclusion, all participants gave their informed consent, and the institutional review board granted ethical clearance. The following inclusion criteria were used to enrol 50 patients who needed fixed dental prostheses or crowns supported by a single implant: they had to be at least 18 years old, require one or more fixed restorations, and have good oral hygiene and sufficient bone support for implant placement. Patients with parafunctional behaviours like bruxism, uncontrolled systemic conditions, or poor compliance with oral hygiene were excluded. Three groups of patients were chosen at random. Prostheses made with CAD-CAM milling were given to Group A (n = 15). Prostheses made with traditional lost-wax or heat-pressed ceramic methods were given to Group B (n = 15). Prostheses made with 3D printing were given to Group C (n = 20), which included definitive zirconia/titanium restorations and provisional restorations made of resin. Groups A and C had digital impressions taken with an intraoral scanner, whereas Group B had traditional impressions taken. Every restoration was made in accordance with established procedures. Marginal fit, fabrication time, complication rate, and patient satisfaction were the main outcome measures. The silicone replica technique was used to assess marginal adaptation, and stereomicroscopy at ×40 magnification was used for

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 3182-3186 | ISSN:2251-6727

examination. From the time an impression was taken to the delivery of the finished restoration, the fabrication time was calculated. A 10-point Visual Analogue Scale (VAS) was used to measure patient satisfaction one week and one month after delivery. Over the course of a 12-month follow-up, complications like debonding, fracture, or surface wear were noted. One-way ANOVA was used for the statistical analysis, and $p < 0.05$ was chosen as the significance level.

Results

At the conclusion of the 12-month follow-up period, all 50 patients had finished the study and been assessed. The results showed that, in a number of parameters, 3D printing (Group C) performed noticeably better than both CAD-CAM milling and traditional fabrication methods. In comparison to CAD-CAM (78.5 ± 12.4 µm) and traditional methods (96.2 ± 14.1 µm), the 3D printing group had the lowest mean marginal discrepancy (52.7 ± 9.8 µm). In addition, the 3D-printed group's fabrication time was significantly shorter (4.2 ± 0.9 hours) than that of the CAD-CAM (8.6 ± 1.2 hours) and traditional methods (12.4 ± 1.5 hours). With a mean VAS score of 9.2, the 3D-printed group had the highest patient satisfaction ratings, whereas the CAD-CAM and conventional groups had lower scores of 7.8 and 6.9, respectively. Compared to CAD-CAM (10%) and conventional fabrication (15%), the 3D printing group experienced the fewest clinical complications (5%). Table 1 provides a clear summary of these results, demonstrating that 3D-printed restorations outperformed the other two groups in terms of accuracy, turnaround time, patient-reported outcomes, and complications. The data demonstrate additive manufacturing's increasing clinical potential as a dependable substitute for conventional restorative workflows.

Table 1. Comparison of outcomes among different fabrication techniques

Parameter	Group A: CAD-CAM Milling (n=15)	Group B: Conventional Technique (n=15)	Group C: 3D Printing (n=20)
Mean marginal discrepancy (µm)	78.5 ± 12.4	96.2 ± 14.1	52.7 ± 9.8
Mean fabrication time (hours)	8.6 ± 1.2	12.4 ± 1.5	4.2 ± 0.9
Patient satisfaction (VAS, 0–10)	7.8 ± 0.6	6.9 ± 0.7	9.2 ± 0.5
Complication rate (%)	10%	15%	5%

Discussion

Clinical workflows in dentistry have changed as a result of the introduction of three-dimensional (3D) printing technologies, especially in prosthodontics and implantology. Numerous studies have examined the accuracy of 3D-printed surgical guides, and the findings indicate that they improve implant placement accuracy when compared to traditional freehand or template-based techniques. According to Yeung et al. (2020) [8], 3D-printed guides guarantee uniform implant placement, reducing operator-dependent variability. This accuracy results in better osseointegration, fewer postoperative complications, and predictable clinical outcomes. These results are further supported by Rouzé l'Alzit et al. (2021) [9], who found that commercial 3D printers produce surgical guides with high accuracy, confirming the technology's status as a vital instrument in contemporary implantology. Beyond implant placement, 3D printing has a broad range of uses in dentistry, including treatment planning, prosthetic fabrication, and diagnostic applications. According to Oberoi et al. (2018) [10], additive manufacturing facilitates every step of the care process, from virtual design and digital scanning to the delivery of the finished prosthetic. Dentistry has been able to transition from conventional analogue techniques to more effective, patient-centered digital workflows thanks to this thorough integration. 3D printing has made it possible to create biomimetic scaffolds for tissue regeneration in regenerative dentistry, another area with emerging applications. According to Zhao et al. (2024) [11], dental tissue engineering requires precise control over scaffold architecture, which additive manufacturing offers. The potential of bioprinting in alveolar tissue regeneration was also highlighted by Ostrovidov et al.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 3182-3186 | ISSN:2251-6727

(2023) [12], where cell-rich constructs might promote bone and periodontal regeneration. These regenerative uses show that 3D printing can affect both mechanical and biological results, extending its use beyond prosthetics. 3D-printed full dentures have been studied as an alternative to traditional prosthodontic techniques. Patients reported good comfort, function, and appearance, according to Abdelnabi and Swelem (2024) [13], confirming 3D-printed dentures as a trustworthy substitute. These results demonstrate that additive manufacturing offers special advantages like quicker turnaround times and greater customisation rather than just replicating traditional workflows. However, printer technology and material quality affect how accurate 3D-printed guides and restorations are. In their comparison of several printers, Morón-Conejo et al. (2024) [14] found notable variations in accuracy, highlighting the importance of choosing the right tools for clinical use. Similar to this, Refaie et al. (2024) [15] showed that zirconia crowns can be produced with remarkable precision using digital light processing (DLP) printing, providing a good substitute for subtractive CAD-CAM techniques. These results highlight how crucial it is to optimise technology in order to guarantee clinically valid results. Looking at more general patterns, Chander and Gopi (2024) [16] noted that 3D printing is becoming more and more accepted by clinicians and incorporated into standard prosthodontics. This long-term trend reflects both the advancement of technology and the change in professional perspectives regarding digital workflows. By talking about the additive manufacturing of metallic implant components, which enables previously unheard-of customisation and biomechanical performance, Revilla-León et al. (2020) [17] expanded on this viewpoint. These results were confirmed by Duplák et al. (2025) [18], who emphasised that additive manufacturing is turning into a key component of implant manufacturing because of its adaptability in design and capacity to produce patient-specific solutions. Randomised controlled trials have also confirmed the clinical effectiveness of 3D-printed crowns. According to Cai et al. (2025) [19], 3D-printed zirconia crowns are a dependable option for restorative dentistry because of their exceptional fit, stability, and longevity. These findings were corroborated by Holban et al. (2025) [20], who emphasised how 3D printing enhances prosthodontic workflows, increasing productivity without sacrificing quality. Similar to this, Jun et al. (2025) [21] noted that 3D printing has clinical uses in a variety of dental fields, despite ongoing restrictions like material standardisation and regulatory issues. More complex protocols and improved printable materials have been especially helpful for implant dentistry. According to Alqutaibi et al. (2024) [22], these advancements help ensure better integration of implants and prostheses through precision-based rehabilitation. Additionally, in vitro research by Elsayed et al. (2025) [23] demonstrated that 3D-printed zirconia crowns have a better marginal fit than milled counterparts, providing increased accuracy that is essential for long-term clinical success. When choosing a crown, wear resistance is still crucial, particularly for posterior teeth that are subjected to high occlusal forces. In their investigation of 3D-printed nano-hybrid resin crowns, Ghabchi et al. (2025) [24] discovered encouraging wear resistance in both primary and permanent molars. Their results suggest that 3D-printed crowns can withstand clinical stresses while maintaining functionality and aesthetics. Compared with CAD-CAM zirconia and ceramics, the nano-hybrid resin crowns showed competitive performance, reinforcing their potential as cost-effective yet durable restorative options. When combined, these results show that 3D printing is no longer limited to specialised or experimental uses. Instead, it is rapidly establishing itself as a mainstream approach in implantology, prosthodontics, and regenerative dentistry. While challenges such as material consistency, long-term data, and clinical standardization remain, the evidence strongly supports its transformative role in dental practice. The convergence of accuracy, efficiency, and patient satisfaction underscores the promise of 3D printing as a cornerstone of future dental care.

Conclusion

In comparison to CAD-CAM and traditional techniques, this hospital-based study showed that 3D-printed prostheses and implant-supported restorations offer better marginal accuracy, shorter fabrication times, and greater patient satisfaction.
Its clinical reliability was confirmed by the fact that the 3D printing group experienced the fewest complications. These results demonstrate how additive manufacturing has the potential to revolutionise restorative dentistry. As a practical substitute for conventional workflows, 3D printing guarantees effectiveness and better patient-centered results.

References

1. Dawood A, Marti Marti B, Sauret-Jackson V, Darwood A. 2015 Dec;219(11):521-9. PMID: 26657435.
2. Revilla-León M, Özcan M.J Prosthodont. 2019 Feb;28(2):146-58. PMID: 29682823.
3. Revilla-León M, Sadeghpour M, Özcan M. Odontology. 2020 Jul;108(3):331-8.. PMID: 31264008.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 3182-3186 | ISSN:2251-6727

4. Tian Y, Chen C, Xu X, Wang J, Hou X, Li K, et al. Biomed Res Int. 2021 Jul 17;2021:9950131. PMID: 34367410.
5. Prasad S, Abdul Kader N, Sujatha G, Raj T, Patil S. 2018;5(2):89-91. doi:10.2217/3dp-2018-0012.
6. Rezaie F, Farshbaf M, Dahri M, Masjedi M, Maleki R, Amini F, et al. 2023 Feb;7(2):80.. PMID: 38645939.
7. Huang S, Wei H, Li D. 2023 Jan 20;11:1100155. PMID: 36741746.
8. Yeung M, Abdulmajeed A, Carrico CK, Deeb GR, Bencharit S. J Prosthet Dent. 2020 Jun;123(6):821-8. PMID: 31653399.
9. Rouzé l'Alzit F, Cade R, Naveau A, Babilotte J, Meglioli M, Catros S. J Dent. 2021;109:103909. doi:10.1016/j.jdent.2021.103909.
10. Oberoi G, Nitsch S, Edelmayer M, Janjić K, Müller AS, Agis H. 2018 Nov 22;6:172.. PMID: 30525032.
11. Zhao F, Zhang Z, Guo W. Front Bioeng Biotechnol. 2024 Feb 22;12:1356580. PMID: 38456006.
12. Ostrovidov S, Ramalingam M, Bae H, Orive G, Fujie T, Shi X, et al.Front Bioeng Biotechnol. 2023 Apr 14;11:991821. PMID: 37122863;.
13. Abdelnabi MH, Swelem AA. Cureus. 2024 Sep 19;16(9):e69698.. PMID: 39308835.
14. Morón-Conejo B, Berrendero S, Salido MP, Zarauz C, Pradíes G.J Dent. 2024 Sep;148:105226. PMID: 38971459.
15. Refaie A, Bourauel C, Elshazly T, Evers-Dietze B, Alhotan A, Aldesoki M. J Dent. 2024;147:105151. doi:10.1016/j.jdent.2024.105151.
16. Chander NG, Gopi A.. 2024 Jun;80(4):399-403. PMID: 39071750.
17. Revilla-León M, Sadeghpour M, Özcan M. J Prosthodont. 2020 Jun;29(6):579-88. doi:10.1111/jopr.13212.
18. Duplák J, Dupláková D, Yeromina M, Mikuláško S, Török J. Sci. 2025;7(3):109. doi:10.3390/sci7030109.
19. Cai F, Wang Y, Jiang J, Wu W, Lu H, Ye T, et al. J Dent. 2025;138:106069. doi:10.1016/j.jdent.2025.106069.
20. Holban CC, Tatarciuc M, Vitalariu AM, Vasluianu RI, Antohe M, Diaconu DA, et al.. J Clin Med. 2025 Jul;14(14):4837.PMID: 40725530;
21. Jun MK, Kim JW, Ku HM.. Oral. 2025;5(2):24. doi:10.3390/oral5020024.
22. Alqutaibi AY, Alghauli MA, Aljohani MH, Zafar MS. Bioprinting. 2024;27:e00356. doi:10.1016/j.bprint.2024.e00356.
23. Elsayed MS, El-Kouedi AY, Shokry TE.. BMC Oral Health. 2025 Feb;25:221.PMID: 39934766.
24. Ghabchi B, Mavi F, Çömlekoğlu E, Saklakoğlu IE, Uzel I. J Prosthet Dent. 2025 Feb. doi:10.1016/j.prosdent.2025.02.040.