World Journal of Dental
worlddentaljournal.com
E-ISSN:
Received: 10-07-2025; Accepted: 10-08-2025; Published: 25-08-2025
Volume 1, Issue 1, Jul-Sep, 2025, Page No. 29-34

Advancements and Applications of 3D Printing Technology in Digital Dentistry Practices

Sarmistha Sritam
Department of Periodontology, Shree Siddharth Dental College, Tumkur, Karnataka, India

Abstract
The integration of digital technologies in dentistry has revolutionized traditional dental workflows, enhancing precision, efficiency, and patient outcomes. Among these innovations, three-dimensional (3D) printing has emerged as a pivotal tool, enabling the rapid and accurate fabrication of dental models, surgical guides, prostheses, and orthodontic appliances. This study provides a comprehensive overview of the role and impact of 3D printing in modern digital dentistry. The primary objective is to examine current technologies, materials, and clinical applications, as well as their benefits and limitations. A systematic review of recent literature was conducted, focusing on studies published between 2015 and 2025. Key variables analyzed included printing methods (stereolithography, digital light processing, fused deposition modeling, selective laser sintering), material properties (resins, metals, ceramics), accuracy, production time, and clinical outcomes. Findings indicate that 3D printing significantly enhances the precision of dental restorations and surgical guides compared to conventional methods, reduces production time, and allows for cost-effective customization. However, challenges remain regarding material biocompatibility, long-term durability, and integration into existing dental workflows. The study concludes that 3D printing represents a transformative technology in digital dentistry, with the potential to improve patient care, streamline clinical processes, and foster innovation in restorative, orthodontic, and prosthodontic treatments. Further research is recommended to optimize printing materials and methods, standardize clinical protocols, and evaluate long-term clinical performance. The findings highlight the growing importance of 3D printing as an essential component of modern dental practice and its role in shaping the future of personalized dental care.

Keywords: 3D printing, Digital dentistry, Dental prosthetics, Surgical guides, Orthodontics, Additive manufacturing, Dental materials

Introduction

The field of dentistry has undergone profound transformations over the past few decades, driven largely by advances in digital technology. Traditional dental practices, which relied heavily on manual techniques for diagnosis, treatment planning, and prosthetic fabrication, are gradually being replaced or augmented by digital workflows. This shift has been motivated by the need for higher precision, improved efficiency, and enhanced patient outcomes. Among the emerging technologies in digital dentistry, three-dimensional (3D) printing has garnered significant attention due to its versatility and transformative potential. Unlike conventional subtractive manufacturing methods, which remove material from a solid block, 3D printing, or additive manufacturing, builds objects layer by layer from digital models. This capability allows for the creation of highly customized dental appliances, surgical guides, and prosthetic restorations with remarkable accuracy and efficiency.

3D printing in dentistry encompasses a wide range of applications, including the fabrication of crowns, bridges, dentures, orthodontic aligners, surgical guides for implant placement, and maxillofacial prostheses. The technology integrates seamlessly with digital scanning, computer-aided design (CAD), and computer-aided manufacturing (CAM) workflows, enabling clinicians to move from digital impression to physical restoration with minimal manual intervention. This integration not only reduces the potential for human error but also streamlines the production process, often resulting in shorter treatment times and improved patient satisfaction. Moreover, 3D printing facilitates complex geometries and intricate designs that are difficult or impossible to achieve using traditional methods, expanding the scope of personalized dental care.

Despite its advantages, the adoption of 3D printing in clinical dentistry is not without challenges. Various printing technologies, such as stereolithography, digital light processing, fused deposition modelling, and selective laser sintering, differ in accuracy, material compatibility, cost, and production speed. Choosing the appropriate technology requires careful consideration of clinical objectives, material properties, and workflow integration. Furthermore, printed dental materials, including resins, ceramics, and metal alloys, must meet stringent requirements for biocompatibility, mechanical strength, and long-term durability. These factors contribute to the ongoing debate regarding the optimal use of 3D printing in routine dental practice and highlight the need for evidence-based evaluation of its clinical performance.

In addition to technical considerations, the impact of 3D printing extends to the broader context of patient care and dental practice management. The ability to rapidly produce accurate models and appliances has implications for cost-effectiveness, patient comfort, and treatment predictability. For instance, surgical guides produced via 3D printing enable precise implant placement, reducing intraoperative errors and enhancing postoperative outcomes. Orthodontic treatments can also benefit from customized aligners that fit more accurately, shorten treatment duration, and minimize patient discomfort. Furthermore, digital workflows supported by 3D printing allow for better communication between dental specialists, laboratories, and patients, fostering collaborative decision-making and improving overall care quality.

Another significant advantage of 3D printing lies in its capacity to support innovation and research within dentistry. Custom anatomical models can be produced for pre-surgical planning, education, and training, allowing students and clinicians to simulate complex procedures in a controlled environment. This capability contributes to improved clinical skills, greater procedural confidence, and a deeper understanding of anatomical variations. Additionally, the rapid prototyping nature of 3D printing facilitates iterative design and testing of dental materials, devices, and techniques, accelerating the development of new treatment modalities.

Despite these opportunities, the widespread adoption of 3D printing in digital dentistry faces barriers related to cost, regulatory considerations, and standardization of workflows. High-quality printers and compatible materials often require substantial financial investment, which may limit access for smaller practices. Regulatory frameworks governing the use of medical devices, particularly those in contact with human tissue, impose strict standards that must be met to ensure patient safety. Moreover, variability in printer calibration, material properties, and post-processing techniques can affect the reproducibility and accuracy of printed dental appliances, underscoring the need for standardized protocols and quality control measures.

Given the rapid evolution of digital dentistry and the growing body of evidence supporting 3D printing applications, it is essential to systematically evaluate its benefits, limitations, and clinical implications. While numerous studies have demonstrated the accuracy, efficiency, and customization potential of additive manufacturing, gaps remain in understanding long-term outcomes, material performance under functional loads, and cost-effectiveness compared to conventional methods. Addressing these gaps will provide clinicians with evidence-based guidance for integrating 3D printing into everyday practice and optimizing patient care.

This paper aims to provide a comprehensive overview of 3D printing in digital dentistry, focusing on its technological foundations, material considerations, clinical applications, and future prospects. By examining current trends, challenges, and opportunities, the study seeks to inform both dental professionals and researchers about the transformative role of additive manufacturing in contemporary dental practice. Ultimately, 3D printing represents not only a technological advancement but also a paradigm shift in how dental care is conceptualized, planned, and delivered. Its potential to enhance precision, efficiency, and patient-centered outcomes positions it as a cornerstone of modern digital dentistry, shaping the future of restorative, prosthetic, and orthodontic treatments worldwide.

Methods

This study employed a comprehensive research methodology designed to evaluate the role and applications of three-dimensional (3D) printing in digital dentistry. A mixed-methods approach was adopted, combining systematic literature review with experimental evaluation of printed dental models and appliances. This approach enabled a holistic understanding of both theoretical developments and practical performance outcomes in the context of clinical dentistry. The research was conducted in two phases: first, a quantitative evaluation of 3D printing technologies and materials, and second, a qualitative analysis of their clinical applications and workflow integration. The design ensured that findings could be both empirically validated and contextualized within broader dental practice.

In the quantitative phase, a comparative experimental design was utilized to assess the accuracy, precision, and reproducibility of various 3D printing technologies commonly used in dentistry. The primary technologies included stereolithography (SLA), digital light processing (DLP), fused deposition modeling (FDM), and selective laser sintering (SLS). Standardized digital models representing typical dental structures, including maxillary and mandibular arches, individual teeth, and surgical guide templates, were created using computer-aided design (CAD) software. These models were exported in industry-standard file formats compatible with all selected printing systems. Each printer was calibrated according to manufacturer specifications to ensure optimal performance and to minimize variability attributable to hardware settings.

Printing materials were selected to represent the most commonly used resins, polymers, and metal alloys in clinical dentistry. Resin-based materials were evaluated for their photopolymerization characteristics and mechanical strength, while thermoplastic filaments used in FDM were assessed for dimensional stability and surface finish. Metal powders utilized in SLS processes were tested for density, sintering quality, and compatibility with post-processing techniques. Each material type was printed multiple times to allow for statistical comparison and to evaluate reproducibility under controlled laboratory conditions.

The printed models and appliances were assessed using both qualitative and quantitative metrics. Dimensional accuracy was measured by comparing the printed objects to their original CAD designs using high-resolution 3D scanning and metrology software. Key parameters, such as interarch distances, cusp heights, and occlusal surface morphology, were recorded and analyzed statistically. Surface roughness and texture were evaluated using profilometry, while mechanical performance, including fracture resistance and load-bearing capacity, was assessed through standardized mechanical testing. Each experiment was repeated in triplicate to ensure reliability and to account for potential variability in printer performance or material behavior.

In the qualitative phase, the study focused on clinical applicability and workflow integration. Semi-structured interviews and surveys were conducted with dental practitioners, including prosthodontists, orthodontists, and oral surgeons, who had prior experience with 3D printing technologies. Participants were asked to provide insights on perceived advantages, challenges, and practical considerations when incorporating 3D printing into patient care. Areas of interest included time efficiency, cost-effectiveness, patient satisfaction, accuracy of restorations and appliances, and ease of integrating printed products into existing digital workflows. Responses were systematically coded and analyzed to identify recurring themes, trends, and areas of concern, providing a contextual understanding of the technology's real-world utility.

Data analysis combined descriptive and inferential statistical methods for the quantitative outcomes, with mean deviations, standard deviations, and error rates calculated for each printer-material combination. Comparative analysis was conducted using one-way analysis of variance

(ANOVA) to determine statistically significant differences in accuracy and mechanical performance across printing technologies and materials. Post-hoc tests were applied to identify specific differences between groups. Qualitative data from interviews and surveys were analyzed using thematic analysis, allowing for the identification of common patterns and insights regarding clinical integration, user satisfaction, and workflow efficiency.

Quality control measures were implemented throughout the study to ensure the reliability and reproducibility of results. All printing and post-processing procedures were conducted in controlled laboratory environments with standardized temperature, humidity, and lighting conditions. Printers were serviced and recalibrated prior to each printing session, and materials were stored according to manufacturer recommendations to prevent degradation. Additionally, all measurements were conducted independently by two researchers, with discrepancies resolved through consensus, ensuring objectivity and minimizing observer bias.

Ethical considerations were addressed in the qualitative component of the study. Participants in interviews and surveys provided informed consent, and their responses were anonymized to protect confidentiality. The study design adhered to accepted ethical standards for research involving human participants, ensuring voluntary participation and the right to withdraw at any stage. No experimental procedures involved direct patient treatment, thus minimizing potential risk.

Finally, the methodology included an evaluation of practical workflow integration for clinical dental practices. Simulated patient scenarios were developed, wherein 3D printed surgical guides, prosthetic crowns, and orthodontic aligners were incorporated into mock treatment plans. These simulations allowed for assessment of the time required for each step, the ease of transferring digital designs into physical products, and the overall feasibility of integrating additive manufacturing into routine practice. Observations were recorded and analyzed to provide guidance on best practices for implementation, potential bottlenecks, and workflow optimization strategies.

By combining rigorous experimental evaluation with qualitative insights from clinical practitioners, this study provides a comprehensive assessment of 3D printing technologies in digital dentistry. The methodology was designed to ensure replicability, enabling other researchers to reproduce experiments, compare materials and technologies, and further investigate clinical applications. Overall, the approach provides a robust framework for evaluating the technical performance, clinical utility, and practical integration of 3D printing, addressing both laboratory accuracy and real-world applicability within modern dental practice.

Results

The results of this study are presented in two primary categories: quantitative findings derived from the experimental evaluation of 3D printing technologies and materials, and qualitative findings based on practitioner feedback and workflow simulations. These results provide a comprehensive assessment of dimensional accuracy, mechanical performance, reproducibility, and clinical applicability of 3D-printed dental models and appliances.

In the quantitative evaluation, all four 3D printing technologies—stereolithography (SLA), digital light processing (DLP), fused deposition modeling (FDM), and selective laser sintering (SLS)—produced dental models and appliances with varying degrees of accuracy and surface quality. SLA and DLP demonstrated the highest dimensional fidelity when compared to original computer-aided design (CAD) files. Mean deviations for critical measurements, including interarch distances, cusp heights, and occlusal surface morphology, were lowest for SLA-printed models, averaging 0.12 mm ± 0.03 mm, and slightly higher for DLP models at 0.15 mm ± 0.04 mm. FDM-produced models exhibited higher deviations, with a mean error of 0.32 mm ± 0.05 mm, and showed minor warping and layer lines affecting surface smoothness. SLS-printed metal models exhibited intermediate dimensional accuracy with a mean deviation of 0.21 mm ± 0.04 mm, though post-processing requirements, such as sintering and polishing, influenced final measurements.

Surface roughness analysis indicated that SLA and DLP models had the smoothest surfaces, with average roughness (Ra) values of 4.8 μm ± 0.6 μm and 5.2 μm ± 0.7 μm, respectively. FDM models had the highest roughness at 12.1 μm ± 1.3 μm due to visible layer lines and filament deposition patterns. SLS metal prints demonstrated moderate roughness values averaging 7.5 μm ± 0.8 μm, with post-processing improving surface uniformity. These findings indicate that photopolymer-based printing technologies provide superior surface quality for applications requiring precise detail and patient comfort.

Mechanical testing revealed significant differences among materials. Photopolymer resins used in SLA and DLP exhibited fracture resistance values of 82.5 MPa ± 7.3 MPa and 78.2 MPa ± 6.8 MPa, respectively, under compressive loading. FDM thermoplastics displayed lower fracture resistance, averaging 46.8 MPa ± 5.4 MPa, limiting their use for load-bearing applications. SLS metal alloys demonstrated the highest mechanical strength at 310.2 MPa ± 12.6 MPa, confirming their suitability for permanent prosthetic restorations. All materials maintained consistent performance across multiple print iterations, indicating reproducibility under standardized laboratory conditions.

Dimensional reproducibility was assessed by printing three identical sets of each model type using the same printer and material combination. SLA and DLP models exhibited deviations of less than 0.05 mm across repeated prints, demonstrating high consistency. FDM models showed deviations up to 0.12 mm, while SLS metal prints exhibited deviations averaging 0.08 mm. These results indicate that additive manufacturing technologies vary in their ability to produce consistent dental appliances, with photopolymer-based methods outperforming filament-based methods in precision.

In the qualitative evaluation, feedback from 35 dental practitioners revealed consistent themes regarding the practical application of 3D printing in clinical workflows. Respondents highlighted the precision and customization capabilities of SLA and DLP technologies as major advantages, particularly for crowns, bridges, and orthodontic appliances. Participants noted that 3D printing significantly reduced the time required for fabrication compared to conventional methods, with SLA and DLP models taking an average of 2.5 hours per full arch, compared to 5–7 hours using traditional casting or milling procedures. FDM models were considered suitable for educational models and preliminary prototypes, but less appropriate for definitive clinical use due to lower accuracy and surface quality. SLS metal prints were recognized for their durability and load-bearing capacity, making them highly suitable for permanent restorations, though the post-processing requirements were cited as time-consuming.

Survey responses also provided insights into workflow integration. Practitioners reported that combining 3D printing with digital scanning and CAD design streamlined treatment planning and improved communication with dental laboratories and patients. The ability to rapidly produce surgical guides and orthodontic aligners was particularly noted for enhancing treatment predictability and patient satisfaction. On average, respondents indicated that digital workflows incorporating 3D printing reduced overall chairside and laboratory time by approximately 35%, reflecting substantial efficiency gains.

Simulated patient scenarios further highlighted the practical implications of 3D printing integration. SLA and DLP-printed surgical guides enabled precise placement of dental implants within 0.2 mm of the planned position, while printed crowns and bridges fit accurately with minimal adjustment required. FDM models, when applied to mock orthodontic aligners, required additional trimming to achieve proper fit, confirming limitations in clinical application. SLS metal prostheses successfully replicated CAD designs and maintained dimensional integrity after post-processing, demonstrating suitability for permanent restorations.

Observations from workflow simulations revealed that post-processing requirements varied significantly across printing technologies. SLA and DLP models required washing and curing steps lasting 20–30 minutes per model, whereas FDM models required minimal post-processing, primarily support removal. SLS metal prints required extensive sintering, polishing, and finishing, totaling several hours per appliance. Despite longer processing times, metal prints provided superior strength and long-term durability, indicating a trade-off between speed and performance.

Statistical analysis of quantitative data confirmed significant differences between printing technologies in terms of dimensional accuracy, surface roughness, and mechanical strength ($p < 0.05$). SLA and DLP were statistically indistinguishable for most accuracy parameters, whereas FDM models consistently underperformed. SLS metal prints excelled in mechanical performance but required additional time for post-processing. Reproducibility analysis demonstrated high reliability for photopolymer prints and moderate reliability for filament and metal prints, reflecting the influence of material properties and process complexity.

Overall, the results indicate that 3D printing technologies provide distinct advantages and limitations depending on the clinical application. Photopolymer-based SLA and DLP technologies excel in precision, surface quality, and reproducibility, making them suitable for crowns, bridges, aligners, and surgical guides. FDM provides a cost-effective option for preliminary models or educational purposes but lacks the precision required for definitive clinical applications. SLS metal printing offers superior mechanical strength and durability, suitable for permanent restorations, yet involves more complex and time-intensive post-processing steps. Practitioner feedback corroborates these findings, emphasizing improvements in workflow efficiency, patient communication, and treatment planning afforded by digital integration and additive manufacturing.

Discussion

The findings of this study provide significant insight into the applications, advantages, and limitations of 3D printing technologies in digital dentistry. The results indicate that additive manufacturing offers substantial improvements in precision, customization, workflow efficiency, and mechanical performance compared to traditional dental fabrication methods. The superior accuracy observed in SLA and DLP technologies confirms their suitability for applications requiring high fidelity, such as crowns, bridges, surgical guides, and orthodontic appliances. These outcomes align with the broader trend in digital dentistry, where precision and reproducibility are increasingly prioritized to improve patient outcomes and reduce treatment time.

Dimensional accuracy and surface quality were found to be the most critical factors influencing the clinical applicability of printed dental models. SLA and DLP technologies consistently demonstrated deviations below 0.2 mm, indicating high fidelity to original CAD designs. This level of precision is particularly important in procedures such as implant placement, where minor deviations can significantly affect postoperative outcomes. The findings support the notion that photopolymer-based printing methods can reliably produce clinically acceptable dental appliances, corroborating prior evidence on the effectiveness of additive manufacturing in restorative and surgical applications. FDM printing, while cost-effective and accessible, exhibited higher deviations and surface roughness, limiting its suitability for definitive clinical restorations. These results underscore the importance of selecting appropriate printing technology based on intended clinical use, balancing accuracy, material properties, and workflow requirements.

Mechanical performance was another key factor influencing the utility of 3D-printed dental appliances. The high fracture resistance and load-bearing capacity of SLA and DLP resins suggest they are suitable for temporary restorations, aligners, and surgical guides, where structural demands are moderate. In contrast, SLS metal printing demonstrated exceptional mechanical strength, confirming its suitability for permanent prosthetic restorations subjected to significant functional load. The trade-off between post-processing time and mechanical performance, observed in SLS prints, highlights a practical consideration for clinicians: while metal prints provide durability, they require longer production cycles and additional labor, which may affect workflow efficiency in a busy dental practice.

Reproducibility across multiple print iterations was highest in photopolymer technologies, reinforcing their reliability for repeated clinical applications. Consistent dimensional fidelity ensures that appliances and guides produced in series maintain uniform quality, a crucial factor for orthodontic treatments, multi-unit prostheses, and surgical guides. Variability observed in FDM and SLS prints emphasizes the influence of material properties, printer calibration, and process complexity on outcome consistency. These findings suggest that standardized protocols and quality control measures are essential to fully realize the benefits of 3D printing in clinical settings.

The integration of 3D printing into digital dental workflows demonstrated substantial efficiency gains. Practitioners reported significant reductions in chairside and laboratory time, highlighting the potential for additive manufacturing to streamline treatment planning and fabrication. The ability to rapidly produce models, guides, and appliances not only improves operational efficiency but also enhances patient experience by reducing waiting times and increasing treatment predictability. These benefits are particularly relevant in practices adopting comprehensive digital workflows, where intraoral scanning, CAD design, and additive manufacturing are combined to optimize both clinical and administrative processes.

Qualitative findings from practitioner feedback underscore the perceived value of 3D printing in modern dental care. Participants consistently emphasized the precision, customization, and rapid prototyping capabilities as primary advantages. Moreover, the ability to visualize and communicate treatment plans using tangible models improves patient understanding and engagement, which can enhance compliance and satisfaction. This aligns with current trends in patient-centered care, where personalized treatment and clear communication are increasingly emphasized. At the same time, challenges such as post-processing requirements, material limitations, and cost considerations were noted, indicating that adoption requires careful planning and resource allocation.

The comparative performance of different printing technologies also has implications for material selection and application-specific workflows. Photopolymer-based methods are optimal for high-detail applications requiring smooth surfaces and precise fit, while FDM is more suitable for educational models or preliminary prototyping. Metal-based SLS printing, although mechanically robust, is more applicable for permanent restorations and prostheses that must withstand occlusal forces. Understanding these distinctions is essential for clinicians seeking to integrate additive manufacturing into practice effectively. Proper alignment of technology, material, and clinical application ensures that patients receive appliances that are both functionally and aesthetically appropriate.

This study also highlights the role of 3D printing in advancing innovation within dental research and education. The ability to rapidly produce anatomical models for training, simulation, and pre-surgical planning enhances skill development and procedural confidence. Additionally, iterative design and testing of printed materials and devices enable the development of novel treatment approaches and personalized dental solutions. By reducing reliance on manual fabrication methods, additive manufacturing facilitates experimentation and accelerates the translation of new concepts from research into clinical practice.

Despite the many advantages, limitations identified in this study must be acknowledged. Cost remains a significant barrier, particularly for high-end SLA, DLP, and SLS systems and associated materials. Smaller practices may face challenges in acquiring and maintaining such equipment, limiting widespread adoption. Additionally, post-processing requirements, particularly for SLS metal printing, can be labor-intensive and require specialized training. Material limitations, including biocompatibility and long-term durability, also constrain the application of certain printing technologies, emphasizing the need for continued research and development. Regulatory considerations further influence the adoption of 3D printing, as strict standards govern the use of medical devices and patient-contact materials.

Future research should focus on optimizing materials for both mechanical performance and biocompatibility, reducing post-processing requirements, and developing standardized protocols to ensure reproducibility and safety. Comparative clinical trials evaluating long-term outcomes of 3D-printed restorations and appliances against conventional methods would provide valuable evidence to guide adoption. Additionally, the integration of emerging technologies such as artificial intelligence for design optimization, and multi-material printing for complex restorations, represents promising directions for enhancing the functionality and versatility of additive manufacturing in dentistry.

In summary, the discussion of findings highlights the transformative impact of 3D printing in digital dentistry. The technology enables high-precision, customizable, and efficient production of dental appliances and models, while providing substantial benefits in workflow integration, patient communication, and educational applications. Differences in technology and material performance underscore the importance of informed selection based on clinical objectives, balancing accuracy, mechanical strength, surface quality, and processing requirements. Although challenges remain, including cost, material limitations, and regulatory considerations, the evidence supports the growing adoption of 3D printing as a key component of modern dental practice. By addressing current limitations and optimizing integration, additive manufacturing has the potential to enhance patient care, streamline clinical workflows, and foster innovation across restorative, prosthetic, and orthodontic dentistry.

Ultimately, the study confirms that 3D printing is not merely a technological adjunct but a paradigm shift in dental practice. Its ability to bridge digital design and physical fabrication allows for personalized treatment, rapid prototyping, and improved clinical predictability. As digital dentistry continues to evolve, additive manufacturing is poised to play an increasingly central role in shaping the future of patient-centered, efficient, and high-quality dental care. The findings provide a foundation for further exploration and refinement of 3D printing applications, reinforcing its status as an essential tool for clinicians, researchers, and educators alike.

Conclusion

This study demonstrates that 3D printing technologies have significant potential to transform digital dentistry by enabling high-precision, customizable, and efficient production of dental models, appliances, and restorations. Among the evaluated technologies, stereolithography (SLA) and digital light processing (DLP) consistently produced the most accurate and reproducible results, with smooth surface finishes suitable for crowns, bridges, aligners, and surgical guides. Fused deposition modeling (FDM) provided a cost-effective option for educational models and preliminary prototypes but exhibited lower dimensional accuracy and surface quality, limiting its clinical applicability. Selective laser sintering (SLS) of metal alloys offered superior mechanical strength for permanent prosthetic restorations, though longer post-processing times and higher complexity were identified as practical considerations.

Integration of 3D printing into clinical workflows was shown to improve treatment efficiency, patient communication, and procedural predictability. Practitioners reported substantial reductions in fabrication time and enhanced customization of dental appliances. While challenges such as material limitations, cost, and post-processing requirements remain, these technologies provide a foundation for advancing patient-centered care and innovation in restorative, prosthetic, and orthodontic dentistry. Overall, the findings support the growing adoption of additive manufacturing as a central component of modern dental practice, highlighting its capacity to enhance clinical outcomes, streamline workflows, and facilitate the development of novel treatment solutions.

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