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APPLICATION OF 3D TECHNOLOGIES IN DENTISTRY

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Abstract: This article provides a comprehensive review of the use of 3D (three-dimensional) technologies in dentistry, their historical development, main types, and practical applications. The study examines 3D scanning (intraoral scanners and CBCT), CAD/CAM systems, and 3D printers used for the fabrication of prostheses, surgical guides for implant placement, orthodontic appliances (such as aligners), reconstructive surgery, and educational purposes. The discussion also includes materials, biocompatibility, advantages, and limitations, as well as the current situation and prospects in Uzbekistan. Based on recent literature and systematic reviews, it is shown that 3D technologies play a crucial role in improving individualization, accuracy, and efficiency in dentistry.

Keywords: Dentistry, 3D technology, 3D scanning, intraoral scanner, CBCT, CAD/CAM, 3D printing, implantology, orthodontics.

Introduction

Over the past decades, dentistry has transitioned from traditional analog techniques to digital approaches. At the core of this transformation lie 3D technologies — including intraoral and laboratory scanning, computer-aided design (CAD), computer-aided manufacturing (CAM), and additive manufacturing (3D printing). These technologies enable clinicians to provide patients with customized, precise, and rapidly produced restorations and devices. The digital workflow integrates every stage — from capturing oral data and CAD modeling to manufacturing with milling machines or 3D printers — enhancing clinical efficiency and consistency. Numerous studies have analyzed both the advantages and limitations of this approach

Main Part

1. Origin and Development of 3D Technologies

3D technologies were first introduced into dentistry through CAD/CAM systems, which initially operated via subtractive manufacturing (milling). Later, additive manufacturing technologies (SLA, DLP, SLM, etc.) became widespread, allowing direct production of dental models, temporary crowns, surgical guides, and even metal or ceramic components. Recent studies confirm the rapid growth and extensive adoption of these technologies in dentistry.

2. 3D Scanning: Intraoral Scanners and CBCT

There are two main methods for acquiring digital data: intraoral scanners (IOS) and the scanning of traditional impressions or plaster models. IOS directly captures highly accurate 3D

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models from the patient's mouth, simplifying the initial stage of the CAD/CAM process. Research indicates that modern IOS devices provide clinically acceptable accuracy and can effectively scan full arches. Meanwhile, CBCT (Cone-Beam Computed Tomography) provides 3D FDM (Fused Deposition Modeling): mostly for prototypes and auxiliary tools. Common materials include dental resins, metal powders (titanium, cobalt-chromium), ceramic composites, and some bioprinting materials. Their biological safety and mechanical properties are under continuous investigation. While many resins demonstrate good biocompatibility, further studies are needed on long-term clinical durability and color stability.

5. Prosthodontics and Dental Prostheses

3D printing has become an essential tool in prosthodontics for creating rapid prototypes and models. Improvements in the mechanical properties of 3D-printed dental resins now allow for the fabrication of temporary and, in some cases, permanent restorations. However, challenges such as long-term strength and color stability remain under study.

6. 3D Technologies in Implantology

For implant placement planning, CBCT and intraoral scan data are combined to design the surgical plan in CAD software. Based on this, static or dynamic surgical guides are fabricated via 3D printing. Systematic reviews confirm that digitally guided implant surgery enhances precision and reduces complications compared to conventional methods. However, absolute accuracy cannot always be guaranteed, as outcomes depend on patient anatomy, guide design, and manufacturing quality.

7. 3D Technologies in Orthodontics

In orthodontics, digital scanning and 3D printing are used for model fabrication, the production of customized aligner series, individualized orthodontic attachments, and even personalized bracket bases. Due to their precision and repeatability, digital workflows are vital for aligner production. Moreover, 3D technologies have proven beneficial in pediatric dentistry for fabricating training models and emergency prototypes.

8. Surgery and Maxillofacial Reconstruction

In reconstructive surgery, 3D models and patient-specific plates simplify surgical planning — allowing preoperative simulation of osteotomies, detection of bone defects, and fabrication of custom implants. Studies show that this approach can shorten operation times and improve outcomes.

9. Endodontics and Conservative Dentistry

In endodontics, 3D-printed models and guides assist in locating canal entries, especially in complex anatomical cases. In restorative dentistry, digital data enables precise and minimally invasive preparation designs for restorations and fillings.

10. Education and Training

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In dental education, 3D-printed anatomical models provide advantages over traditional gypsum models, such as the ability to replicate complex pathologies, allow repeated practice, and ensure standardization. These models improve the efficiency and realism of practical training.

11. Advantages

Individualization: Customized devices based on patient anatomy.

Accuracy: Digital scanning and fabrication reduce errors.

Time Efficiency: Faster production between clinic and laboratory.

Educational Use: Allows creation of standardized, reusable teaching models.

12. Limitations and Risk Factors

Materials: Issues with long-term color stability, mechanical durability, and biocompatibility. Cost: High-quality scanners, CAD software, and 3D printers require significant investment.

Regulatory Requirements: Certification of materials and clinical products is necessary.

Technical Errors: Scanner calibration, design flaws, or printing parameters can affect outcomes

13. The Situation and Prospects in Uzbekistan

Interest in 3D printing and digital dentistry is rapidly growing in Uzbekistan. In Tashkent and other cities, 3D printing services, dental equipment suppliers, and modern digital clinics are emerging. Local laboratories offer dental materials and printing services, while FabLab centers support prototyping and educational activities. Market analyses show increasing demand for 3D dental devices. However, ensuring quality, standardizing materials, and training qualified personnel remain key challenges.

Analysis and Findings

Literature analysis indicates that the adoption of 3D technologies in dentistry improves clinical outcomes, enhances implant and orthodontic treatment planning, and enables personalized patient solutions. Systematic reviews confirm increased implant accuracy and reduced complications; however, each technology has its own inherent limitations. Intraoral scanners often match or exceed traditional impressions in accuracy, though performance varies by device and calibration. Most 3D-printed resins show promising biocompatibility, but long-term clinical data and color stability need further validation. Therefore, clinical adoption should consider case type, cost, material properties, and regulatory standards.

Conclusion

3D technologies have significantly enhanced personalization, precision, and efficiency in dentistry. The integration of intraoral scanning, CBCT, CAD/CAM, and 3D printing has enabled the creation of customized prosthetics, accurately planned implant surgeries, aligners, reconstructive plates, and educational models. However, challenges such as material quality, long-term performance, cost, and regulatory compliance persist. In Uzbekistan, the rapid introduction of digital technologies and the expansion of local 3D printing services mark an

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encouraging trend. The future of dentistry will likely see the rise of bioprinting, AI-assisted design, and cost-effective high-performance materials — ushering in a new era of innovation. To ensure safety and quality, developing clinical standards and continuous professional training programs is essential.

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