International Journal of Biology and Life Sciences
ISSN: 2957-9511 | Vol. 9, No. 2, 2025

The Design and Practice of the Application of Digital Technology in Oral Rehabilitation

Wenjuan Li [1, 2], Shaoqing Zhang [1, 2, *]

[1] Cangzhou Medical College, Cangzhou Hebei, 061000, China
[2] Cangzhou Stomatology Hospital, Cangzhou Hebei, 061000, China

*** Corresponding author:** Shaoqing Zhang

Abstract: This study focuses on the design system and practical application of digital technology in the field of oral restoration. In the current environment of rapid digital development, the field of stomatology is undergoing profound changes. Through a comprehensive analysis of the application of 3D scanning technology for accurate data acquisition, the use of computer-aided design and computer-aided manufacturing (CAD/CAM) technology in denture design and fabrication processes, and virtual reality and augmented reality (VR/AR) technology to assist various surgical scenarios, to comprehensively explore the multifaceted positive role played by digital technology in the process of oral restoration. Digital technology has outstanding advantages in the field of dental prosthetics. Great progress has been made in terms of accuracy, and the average error can be controlled below 50 microns when making dentures. From an efficiency perspective, treatment cycles have been dramatically shortened, with weeks of treatment now reduced to days. The patient experience has also improved significantly. However, there are also some problems that need to be solved in the application of digital technology in oral restoration, such as the high cost of equipment procurement, and the shortage of compound talents who master the professional knowledge and digital technology capabilities of oral medicine. All in all, the future research focus in the field of oral repair should be on the development of cost-effective solutions, the construction of professional personnel training system, and the deep integration with cutting-edge technologies such as artificial intelligence, so as to achieve intelligent, accurate and efficient oral repair. This study is committed to providing theoretical basis and practical guidance for the academic research and clinical practice in this field, and providing forward-looking ideas for the innovative design and extensive application of digital technology in the field of dental prosthesis.

Keywords: Digital Technology; Oral Rehabilitation; CAD/CAM.

1. Introduction

As a key pillar in the field of stomatology, the core mission of oral restoration is to restore the normal physiological function of the mouth and reshape its aesthetic shape for patients with tooth defects or missing diseases. Traditional oral restorations rely heavily on manual skills. Including the use of alginate, silicone rubber and other solid impression materials for impression production, the use of precision technology to make wax, and the use of manual fine-tuning of the restoration and other key steps. There are significant limitations to these traditional processes. First, the operation process is long and complicated, resulting in the treatment cycle often delayed by several weeks, which greatly consumes the time cost of patients; Second, the process of oral medicine professionals physical and energy consumption is huge, the labor intensity is quite high. In addition, due to the inherent error that manual operation is difficult to avoid, the final effect of the restoration often fails to reach the best expectation, which has different degrees of influence on the functional and aesthetic indicators of the restoration [1].

With the rapid development of digitalization, the wide application of digital technology has opened a new chapter in the field of dental prosthetics. Cutting-edge technologies such as 3D scanning technology, computer-aided design (CAD), computer-aided manufacturing (CAM) and virtual reality (VR) have been deeply integrated into this field, fundamentally revolutionizing the planning strategy and implementation path of dental treatment programs. The introduction of digital technology is expected to improve the accuracy, efficiency and overall quality of oral restoration in all aspects. By minimizing the discomfort experience of patients during treatment and significantly shortening the treatment cycle, the overall optimization of patients' medical experience can be realized [2-3].

2. Digital Technology in Oral Rehabilitation Design

2.1. 3D Scanning Technology

Table 1. Traditional impression production compared with an intraoral scanner

Comparison Items	Traditional Impression-taking	Intra-oral Scanner
Accuracy (μm)	±150-±300	±20-±50
Patient Comfort	Low (due to the presence of impression materials in the mouth)	High
Operation Time (min)	15-30	5-10

3D scanning technology is the fundamental support for the digital design of oral restoration. 3D scanners mainly include in-mouth scanners and out-of-mouth scanners. With the patient at the core, the intraoral scanner has achieved a breakthrough in the oral medical industry. The device can scan directly into the patient's mouth, collecting high-resolution 3D data of teeth and oral soft tissues with extreme

accuracy. The comparison and analysis of traditional impression making and intraoral scanner intuitively show the obvious difference between traditional impression making and intraoral scanner, as shown in Table 1.

The traditional impression making method is a mature technology, but this method requires patients to endure the discomfort caused by the filling of the mouth with the impression material for a long time. In contrast, intra-oral scanners offer a non-invasive, more comfortable alternative, significantly reducing the time spent in the dental chair [4].

Extra-oral scanners, on the other hand, are frequently employed for scanning dental models. These scanners can rapidly and accurately acquire the 3D data of dental models, laying the groundwork for seamless subsequent digital design processes. The underlying working principle of 3D scanners is predominantly based on optical triangulation or laser scanning technology. For instance, in optical triangulation, the scanner projects a structured light pattern onto the object's surface. A camera then captures the reflected light, and by leveraging the geometric principles of triangulation (as elucidated by the formula below), the distance information for each point on the object's surface can be computed. This, in turn, enables the reconstruction of a comprehensive 3D model of the object.

where is the distance from the scanner to the measured point, is the baseline distance between the projector and the camera, is the focal length of the camera, and is the displacement of the light spot on the camera image.

2.2. CAD Technology in Oral Restoration Design

As long as 3D data of the mouth or dental mold is obtained through 3D scanning, computer-aided design (CAD) technology can occupy a central position in the design phase. Dental CAD software is a complex and precise tool set, with a series of customized functions, such as tooth preparation design, prosthesis design and occlusion analysis, to meet the diverse needs of oral prosthesis design [5].

In the case of crown design, dentists can use CAD software to simulate the tooth preparation process on a 3D model of a patient's tooth.3D virtual simulation can accurately determine the optimal shape and size of the crown, ensuring that it is tightly fitted to the remaining tooth structure. The detailed procedure for designing dental crowns using CAD software is shown in Table 2.

Bite analysis is another key area where CAD software is of great value. CAD software simulates the complex occlusal relationship between upper and lower teeth, helping dentists identify and correct occlusal interference points. By considering the geometrical model of teeth and material properties, the distribution of bite force was calculated by finite element analysis. The fundamental concept of finite element analysis involves dissecting the intricate dental structure into a series of smaller, more manageable elements. A mechanical model is then established for each element, and through the solution of a system of equations, the stress and strain distribution within the dental structure under occlusal force can be accurately determined. The general form of the finite element equation is: where is the stiffness matrix of the structure, is the displacement vector of the nodes, and is the load vector.

Table 2. Process of designing a dental crown using CAD software

Design Steps	Description
Tooth Model Import	Import the 3D data of the patient's tooth obtained by 3D scanning into the CAD software. This data serves as the foundation for all subsequent design operations.
Tooth Preparation Simulation	Employ the software's specialized tools to simulate the removal of tooth tissue. This step is crucial for creating a shape that can accommodate the crown while maintaining the integrity of the remaining tooth.
Crown Shape Design	Design the outer contour of the crown, taking into account both aesthetic considerations and the occlusal relationship with the opposing teeth. Factors such as tooth color, shape, and alignment are carefully evaluated.
Fit Adjustment	Rigorously check and fine-tune the fit between the crown and the remaining tooth structure. This ensures a tight and proper connection, minimizing the risk of food impaction and ensuring long-term stability.

3. Digital Technology in Oral Rehabilitation Practice

3.1. CAM Technology for Prosthesis Manufacturing

CAM technology is inextricably linked to CAD technology in the digital workflow of oral rehabilitation. Once the prosthesis design is finalized using CAD software, the data is seamlessly transferred to the CAM equipment for fabrication. In the realm of oral rehabilitation, the commonly used CAM equipment includes computer-controlled milling machines and 3D printers [6].

Computer-controlled milling machines are versatile workhorses capable of processing a wide range of dental materials, such as metal, ceramic, and resin, into prostheses with unparalleled precision. Different materials possess distinct processing characteristics and application scenarios, as outlined in Table 3.

3D printers are becoming a revolutionary force in the field of dental prosthetics. The device can print restorations layer by layer with extremely high precision, based on a digital model. The advantages of 3D printing technology are obvious, and the manufacturing process is particularly fast, allowing the restoration to be made within hours, depending on the complexity of the design.3D printing is also exceptional in creating complex shape restorations, which are difficult to achieve with traditional manufacturing methods. The application of multi-material printing function further expands the application space of technology, making it possible to produce restorations with better functionality and aesthetics. Table 4 provides a detailed comparison between 3D printed restorations and those produced by traditional processes.

3.2. Virtual Reality (VR) and Augmented Reality (AR) in Oral Rehabilitation Surgery

VR and AR technologies are gradually making inroads into oral rehabilitation surgery, heralding a new era of precision and enhanced surgical outcomes. Virtual reality (VR) technology resembles a simulated surgical environment. The

technology enables dentists to build a virtual operating platform that allows them to perform risk-free simulations of complex oral surgery, such as dental implants. Through VR pre-operation simulation training, dentists can optimize surgical skills, strengthen hand-eye coordination, and become more confident in handling difficult cases [7].

Table 3. Characteristics and application scenarios of common dental materials processed by CAM

Material	Processing Accuracy (μm)	Mechanical Properties	Application Scenarios
Metal (Titanium alloy)	±20-±30	High strength, excellent corrosion resistance. Titanium alloy is biocompatible, making it suitable for long-term implantation in the oral cavity.	Dental implants, crowns, and bridges. Its high strength can withstand the mechanical forces exerted during chewing.
Ceramic (Zirconia)	±10-±20	High hardness, which ensures durability, and superior aesthetics, closely mimicking the appearance of natural teeth.	Front-tooth crowns, where aesthetics are of utmost importance, and inlays. The high hardness can resist wear and tear over time.
Resin	±30-±50	Moderate strength, which is sufficient for certain applications, and the ability to be easily color-matched to the patient's natural teeth.	Temporary prostheses, which are used during the treatment process, and some inlays where a more cost-effective option is required.

Table 4. 3D printed restorations compared with traditional fabrication methods

Comparison Items	Traditional Manufacturing	3D Printing
Manufacturing Speed	Slow, often involving multiple sequential steps such as casting, milling, and polishing, which can take several days.	Fast, with the ability to complete the manufacturing process within a few hours, significantly reducing the waiting time for patients.
Complexity of Shape	Constrained in creating highly intricate and customized shapes due to the limitations of traditional machining techniques.	Can effortlessly manufacture complex-shaped prostheses, enabling the realization of highly customized designs tailored to the patient's unique oral anatomy.
Material Usage	Prone to more material waste during the machining process, as excess material is often removed to achieve the desired shape.	Exhibits precise material usage, as it builds the prosthesis layer by layer, minimizing waste and optimizing resource utilization.
Cost-effectiveness for Small Batches	Incurs high costs for small-batch production due to the need for tooling and setup, which are expensive and time-consuming.	Cost-effective for small-batch production, as it eliminates the need for costly tooling and setup, making it an ideal choice for customized, one-off prostheses.

Augmented reality (AR) technology, which projects digital information onto the actual surgical area, plays an important role in dental implant surgery. AR glasses are able to project the pre-planned implant position and depth into the patient's jaw area in real time. This real-time guidance provides a visual aid for dentists to reduce the risk of dental implant misalignment. Table 5 details the application and advantages of AR technology in dental implant surgery.

Table 5. Application and Advantages of AR technology in dental implant surgery

Application in Dental Implant Surgery	Description	Advantages
Pre-operative Planning Visualization	AR glasses project the pre-planned implant position and depth onto the patient's jaw area in real-time. This provides dentists with a clear visual representation of the surgical plan, enabling them to accurately assess the feasibility of the procedure.	Facilitates a more comprehensive understanding of the surgical plan, reducing the likelihood of errors during the actual surgery.
Intra-operative Guidance	During the surgery, AR can provide real-time guidance on the drilling depth and angle. This ensures that the implant is placed at the optimal position, taking into account the patient's unique anatomy.	Significantly improves the accuracy of implant placement, minimizing the risk of damaging surrounding tissues such as nerves and blood vessels.
Post-operative Verification	Can be used to verify the actual implant position compared to the pre-operative plan. This allows for immediate identification of any discrepancies and facilitates timely corrective measures.	Ensures that the implant is placed as per the original design, promoting better long-term stability and functionality of the prosthesis.

4. Advantages of Digital Technology in Oral Rehabilitation

4.1. High Accuracy

Digital technology has revolutionized the precision of dental prosthetics to some extent, especially 3D scanning and computer-aided design/computer-aided manufacturing (CAD/ CAM) technology. 3D scanning equipment can obtain more accurate three-dimensional data, which is an important basis for making highly suitable prosthetics for the patient's

mouth. A large number of academic studies have shown that digital technology can control the average error of manufactured restorations within 50 microns. This is a significant improvement over the traditional process. The high precision not only significantly enhances the function of the prosthesis, but also effectively reduces the occurrence of various complications such as food impaction, periodontal disease and premature attrition, which is of great significance for maintaining the long-term oral health of patients [8].

4.2. High Efficiency

Digital technology has streamlined the traditionally cumbersome multi-step oral restoration process. In the past, traditional impression-taking, model making, and prosthesis design could take several days or even weeks. With digital technology, the entire process, from initial 3D scanning to prosthesis manufacturing, can be completed within a matter of days. A comparison of the time required for traditional and digital oral restoration processes, as presented in Table 6, clearly demonstrates the significant time savings offered by digital technology [9].

Table 6. Comparison of the time required for traditional and digital oral restoration processes

Restoration Process	Traditional Method (days)	Digital Method (days)
Impression-taking and Model Making	1-2	0.5 (including 3D scanning)
Prosthesis Design	2-3	1-2 (using CAD software)
Prosthesis Manufacturing	3-5	1-3 (using CAM technology)
Total Time	6-10	2.5-5.5

This reduction in treatment time not only benefits the patient by minimizing the disruption to their daily lives but also allows dental clinics to increase their throughput, serving more patients in a shorter period.

4.3. Improved Patient Experience

Intra-oral scanners have transformed the patient experience by eliminating the discomfort associated with traditional impression-taking materials. Patients no longer have to endure the unpleasant sensation of having impression materials in their mouths for extended periods. Additionally, the shorter treatment time and the more accurate restoration results provided by digital technology contribute to an overall enhanced patient experience. Patients can expect a more comfortable, efficient, and predictable dental treatment, leading to higher satisfaction levels and greater compliance with the treatment plan.

5. Challenges and Solutions of Digital Technology in Oral Rehabilitation

5.1. High Equipment Cost

The introduction of digital equipment such as 3D scanners, CAD/CAM systems, and VR/AR equipment requires significant investment. This is not easy for small and medium-sized dental clinics with limited funds.

How to solve the financial pressure? There are many ways to start. Partnerships can be established between clinics to share equipment, reducing the financial pressure on individual clinics. Or clinics can consider purchasing more affordable, cost-effective basic equipment to meet the needs of diagnosis and treatment while addressing budget constraints. In addition, equipment leasing and applying for special government subsidies are also effective ways to ease financial constraints [10].

5.2. Lack of Professional Talents

The implementation of digital technologies in the field of prosthodontics is highly dependent on professionals with both oral medicine expertise and digital technology capabilities. At present, there is a shortage of such composite professionals. In order to effectively fill the talent gap, it is necessary for dental education institutions to carry out comprehensive and in-depth reform of the current curriculum system and systematically integrate a full range of digital technology-related courses. Courses are required to cover a wide range of key areas, including the principle analysis and practical application of 3D scanning technology, the design logic and operation process of computer aided design/computer aided manufacturing (CAD/CAM) systems, and the innovative application of virtual reality (VR) and augmented reality (AR) technology in oral surgery.

In addition, ongoing education and training programs for practicing dentists are key to ensuring that they are able to accurately grasp and effectively use the latest developments in digital technologies in the field of dental medicine. By carefully organizing professional workshops, high-end academic seminars and high-quality online courses, we can build a dual learning platform for in-service dentists to deepen theoretical knowledge and improve practical skills, and help them achieve professional advancement and breakthrough in the field of digital stomatology [11].

6. Conclusion

In the field of dental prosthetics, the promotion and application of digital technologies are in urgent need of professionals who are proficient in both oral medicine knowledge and digital technology. But now, there is a serious shortage of such interdisciplinary talents, which has become a major obstacle to the development of the industry.

In order to effectively solve the problem of talent dilemma, dental education institutions urgently need to reform the existing curriculum system. A complete teaching system should be formed by combining digital technology-related content comprehensively. The content of the course covers as far as possible the principle explanation and practical operation of 3D scanning technology, the design concept and operation procedure of computer aided design/computer aided manufacturing (CAD/CAM) system, and the innovative application of virtual reality (VR) and augmented reality (AR) technology in oral surgery and other key areas.

It is also critical to provide ongoing learning and training opportunities for practising dentists. Through regular professional workshops, high-end academic seminars, and the development of high-quality online courses, we have successfully built a learning platform combining theory and practice, so that they can timely contact and grasp the latest achievements of digital technology in the field of stomatology, improve professional skills and comprehensive literacy, and help them make greater breakthroughs in the field of digital stomatology. To promote the digital transformation and development of the entire dental prosthodontics industry.

References

[1] Ma Yuhan, Wang Zhe, Fu Baoping. Status and perspectives of digitized processed prosthodontics materials [J]. Chinese Journal of Practical Stomatology, 2025,18 (01): 1-5.

[2] Xie Lihua. Practical application and development of digital technology in prosthodontics [J]. The World of Digital Communications, 2024, (12): 175-177.

[3] Gao Qiaohong, Chen Juanjuan, Chen Xiaolui. Discussion on the application status of digital impression technology for oral scanning [J]. Journal of Traditional Chinese Medicine Management, 2023,31 (17): 175-178.

[4] JUNG S, PARK C, YANG H S, et al. Comparison of different impression techniques for edentulous jaws using three-dimensional analysis. J Adv Prosthodont,2019,11(3):179-186.

[5] Zhu Haoyu. A 3D dental prosthesis design method based on deep learning [D]. Nanjing University of Science and Technology, 2023.

[6] Kim JH, Jeong JH, Lee JH, et al. Fit of lithium disilicatecrowns fabricated from conventional and digital impressions assessed with micro-CT[J].J Prosthet Dent, 2016,116 (4):551-557.

[7] Murbay s,chang ,,Yeung s,et al. Evaluation of the introduction of a dental virtual simulator on the performance of undergraduate dental students in the pre-clinical operative dentistry course [J]. Eur J Dent Educ,2020,24(1):5-16

[8] Liu Dongxu, the application of 3 D registration and 3 D printing technology in stomatology. Shandong University, Shandong University, 2011-11-26.

[9] Cui Aimin, Wang Qi. Research progress and trend of digital restoration technology of removable denture [J]. International Journal of Oral Medicine, 2025,52 (01): 11-17.

[10] Yang Zi yu, flat hair. Clinical application effect of oral digital technology in prosthodontics [J]. The Electronic Journal of General Practice and Oral Medicine, 2020,7 (06): 44.

[11] Li Na, Fu Juan, Zhao Kai. Application of 3 D digital technology in oral anatomical physiology [J]. China Informatization, 2024, (09): 76-77 + 80.